

CHAPTER III

JTWC STUDIES

This Chapter is a collection of studies conducted during the 1965 typhoon season. Some topics appear in their entirety. Other topics are of a continuing nature and will be completed when data becomes available.

The following is a list of the topics discussed in this chapter:

- A. TYPHOON HARRIET - RAPID MOVEMENT BEFORE RECURVATURE
- B. TYPHOONS AMY AND FAYE - UNUSUALLY FAST MOVEMENT AFTER RECURVATURE
- C. AN EXAMPLE OF FALSE RADAR EYE DEVELOPMENT
- D. AN EXAMPLE OF DIFFERENTIAL MOVEMENT AT TWO LEVELS
- E. EXTRATROPICAL SURGE
- F. TIROS VERIFICATION
- G. THE STATISTICAL VERIFICATION PROGRAM
- H. FINAL REPORT ON 700MB NUMERICAL GRID
- I. CHANGES IN SEA SURFACE TEMPERATURE (SST) RESULTING FROM THE TRANSITING OF TYPHOONS SHIRLEY AND TRIX
- J. CHANGES IN MIXED LAYER DEPTH (MLD) RESULTING FROM THE TRANSIT OF TYPHOONS SHIRLEY AND TRIX

A. TYPHOON HARRIET - RAPID MOVEMENT BEFORE RECURVATURE

Typhoon HARRIET was picked up as a tropical depression south southwest of Guam, and remained quasi-stationary for 30 hours, gradually building up to a tropical storm of 35 knots. It then moved north northeast until it was turned to the west by the middle level easterly flow, still as a 35-knot storm.

In the next 12 hours after curving to the west, HARRIET built up to a 65-knot typhoon and accelerated to 24-knot forward speed. For the next $3\frac{1}{2}$ days, until it dissipated over Central China, the storm continued to intensify and moved west northwest at forward speeds of between 16 and 24 knots, with an average forward speed of 18.1 knots. This was in an area where climatology shows an average speed of 11 to 14 knots for this time of year.

A check of the upper air charts for the period showed no indication of any strong easterly "steering current." In fact, the only significant winds were 40-45 knot southerly winds at 700mb in the southeast quadrant of the storm. This is usually considered an indicator of slower movement and intensification. Throughout the period the 500mb and 700mb subtropical ridge to the north remained weak, and all indications pointed to a closed circulation to 300mb, another indicator of slow movement.

The only unusual feature of the storm which did not fit a forecast of slow movement was the building of a north-south ridge at 300mb and 500mb to the east of the storm, with a very flat gradient to the west. This increase of heights behind the storm may have resulted in some form of ageostrophic flow to the west around the storm. However, on the basis of the sparse data available, no definite cause has been found for the rapid movement of the system.

B. TYPHOONS AMY AND FAYE - UNUSUALLY FAST MOVEMENT AFTER RECURVATURE

Typhoon AMY was one of the fastest moving typhoons ever seen in the Western Pacific. It first reached typhoon intensity east of Luzon and immediately started moving north northeast around the western edge of the subtropical high. It accelerated and deepened gradually until, by 260600Z May 1965, it was a 100 knot storm moving north northeast at about 28 knots. At this time it was still a small, shallow, intense system located approximately 180 miles southeast of Okinawa. A fairly deep major trough was located near 123E, with a closed low over the Central China coast at 700mb.

In the next 24 hours the 700mb low deepened and moved to a position south of the tip of Korea, with the trough at 300mb also deepening and moving off the Asian Mainland. Since the subtropical high to the east did not weaken appreciably, a low level jet developed in the air mass surrounding Typhoon AMY, with 700mb wind speeds in excess of 50 knots. Typhoon AMY began to accelerate rapidly, with little decrease in intensity.

By 261800Z, AMY was moving north northeast at about 40 knots, with maximum sustained winds of 80 knots, and by 270000Z it was moving at 46 knots with the storm still of typhoon intensity. Three hours later it crossed the eastern side of Tokyo Bay with wind speeds of about 45 knots and became extratropical northeast of Tokyo.

Another type of system which often moves very rapidly is the typhoon which is becoming extratropical. This type is typical of late or very early season storms. Typhoon FAYE, of November 1965 is an excellent example.

FAYE was a deep storm with a well developed 300mb low at 250000Z and was moving northeast at about 30 knots. At that time, the storm showed indications of an extratropical surge, with a rapid weakening of the eye of the storm and an increase in 700mb temperature at the center from 16 to 21 degrees centigrade in a period of six and one half hours. From the data available, this temperature rise was associated with the destruction of the closed low above 700mb. Immediately after this the storm accelerated rapidly, moving at an average speed of 65 knots between 251200Z and 251800Z. At this time FAYE was technically extratropical, but it still contained winds of over 65 knots and the area covered by winds in excess of 30 knots extended as much as 350 miles from the center.

Using AMY and FAYE as examples, the following are suggested as possible guides to rapid movement of systems which have recurved:

1. Small, intense storms.
2. Shallow storms (top of circulation below 300mb).
3. Storms which are becoming extratropical.
4. Rapid deepening in the major trough position upstream, resulting in a southward movement of the jet stream into the path of the storm.

C. AN EXAMPLE OF FALSE RADAR EYE DEVELOPMENT

When Typhoon DINAH passed over Taiwan on the 18th and 19th of June 1965, it provided a well documented case of false eye development. The false eye was picked up by land radar, TIROS, and both visually and on radar by reconnaissance aircraft (see Figure 3-1) while the actual circulation center was verified by doppler winds.

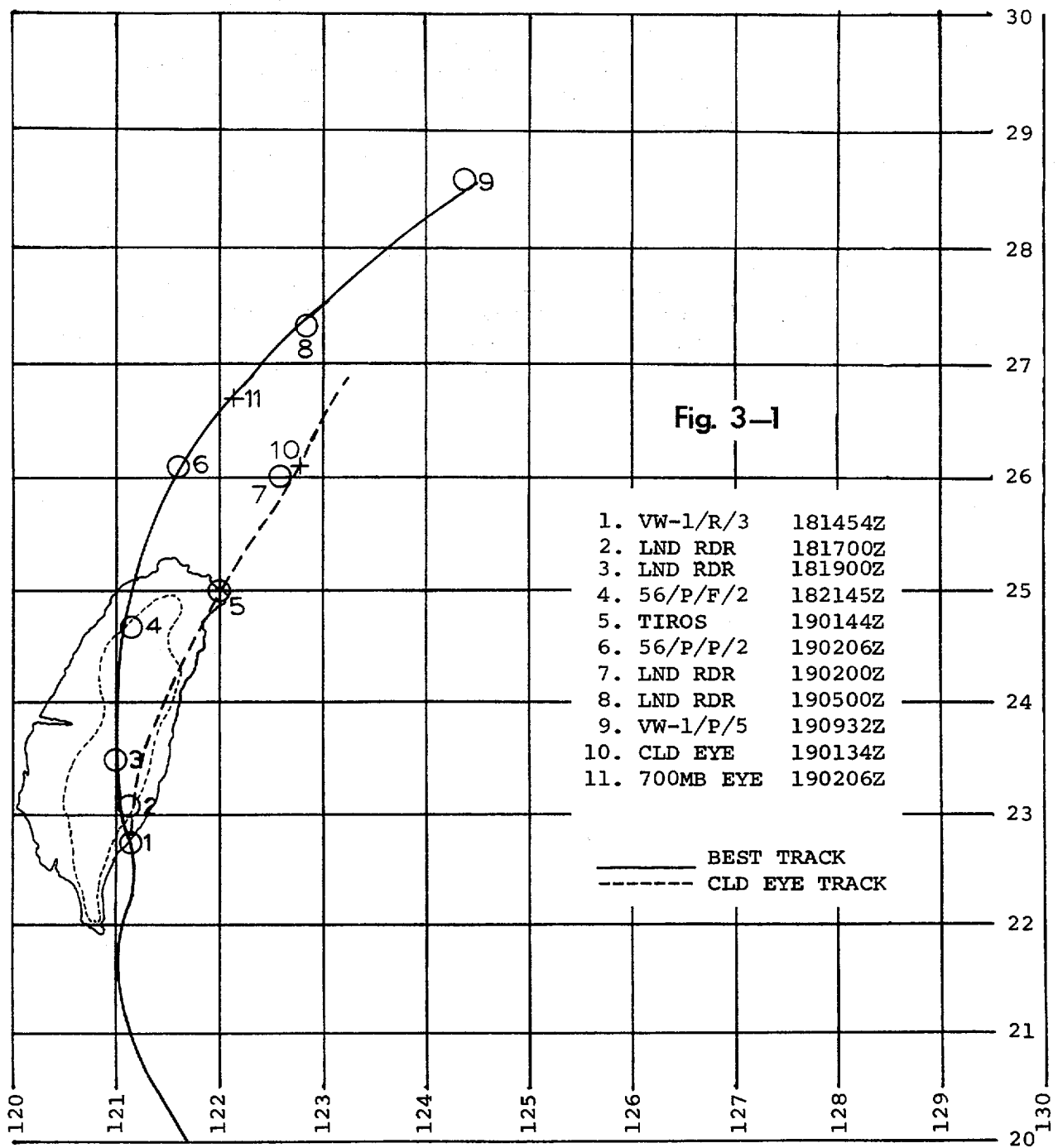
An EC121K aircraft of VW-1 made a radar fix on Typhoon DINAH over the southeast coast of Taiwan at 181454Z. At that time the storm was well defined, with a wall cloud 3-5 miles thick just moving over land. At 181500Z the wall cloud was still well enough defined to be picked up by land radar on Miyako Jima, about 265 miles from the storm. However, by 181900Z the storm center had moved over the central highlands of Taiwan and land radar reported the eye had dissipated, although the center could still be estimated by using spiral overlays on the feeder bands.

At 182145Z an Air Force WB-50, with Captain A. C. Korelishn aboard as Weather Officer made a fix of the 500mb wind center over north central Taiwan. At that time he reported no radar returns or clouds at flight level, but a definite wind circulation. The reconnaissance flight was continued with a 700mb circumnavigation of the island, during which southerly surface winds of 45 knots were observed off the east coast. At 190100Z the aircraft was contacted by a land radar station, which vectored it into a "radar eye" near 26.1N 122.8E. The following is quoted from a post flight report by Captain Korelishn.

"The radar returns were circular in nature and they almost formed a completely closed circle except for the south quadrant. Visible tops ranged from 8-9 to 15 thousand feet. The echo width averaged 4 miles and the intensity of the returns was strong. Once entry had been made into the center of the radar return, it visually showed all signs of a typhoon cloud structure. Circular bands of strato-cumulus, with center tops to 4 thousand feet increasing in height to 8 thousand feet were welded into the wall cloud. The 7/8 cloud coverage allowed sufficient area to view the sea surface. The wind field on the surface was well defined 180-190 degrees at 40 knots while flight level winds at 700mb remained at approximately 210-220/30-35 knots."

After leaving the "cloud eye," the WB-50 put the wind on its wing and located a 700mb wind center at 26.6N 122.2E. Since the surface wind at this point was still approximately 150/25 knots, the search was continued, and a surface wind center located at 26.1N 121.6E at 190206Z. (Approximately 60 miles west of the cloud center). In the meantime, TIROS reported a center at 25.0N 122.0E at 190144Z and Shimen land radar reported an eye at 26.0N 122.6E at 190200Z, near the cloud eye reported earlier by the aircraft.

Land radar reports at 190500Z and a VW-1 penetration at 190932Z indicated that a wall cloud started to form around the surface wind center during the next 12 hours. In fact, VW-1 reported a partial wall cloud 5 miles thick in the northeast quadrant. No further reports were received of the cloud eye to the east, which apparently dissipated.



TRACK OF TYPHOON DINAH OVER TAIWAN
JUNE, 1965

It is interesting to note that, except for airborne reconnaissance, all available data between 181700Z and 190500Z indicated a track at least 60 miles to the right of the actual storm movement, and would undoubtedly have forced a forecast of recurvature well south of Kyushu. Actually, the storm followed the forecast track and moved over central Kyushu as an extra-tropical system.

This "shearing off" of a cloud (and radar) eye during the passage of a storm over a steep mountain range has been observed at least once before, during the passage of Hurricane FRANCES over Guadeloupe Island in the Caribbean Sea on 1 October 1961. It has been suspected in typhoons before, but this is the first case in which synoptic reports of both centers were available.

D. AN EXAMPLE OF DIFFERENTIAL MOVEMENT AT TWO LEVELS

In its early stages, the cyclone that later became Typhoon JEAN was a good example of the damping effect of differential advection on a center.

JEAN was picked up as T.D. 17 on the 26th of July, 1965, between Truk and Eniwetok. At that time, winds of 30 knots were reported, and both low level Southern Hemisphere indrafting and divergence at 200mb favored fairly rapid development.

The 700mb contour pattern and the surface pressure pattern for 270000Z are typical of those occurring in the following three days. The 700mb (and 500mb) patterns showed a weak trough in the westerlies well to the north of the tropical depression, with an almost continuous ridge 10 degrees north of the center and an apparent "steering flow" to the west northwest. On the other hand, the surface pattern showed a deep trough to the north and a comparatively tight gradient in the southerly winds east of the center.

The resulting movement over Guam - and an estimate of the movement of two earlier surface centers - is shown on the attached chart (figure 3-2). The 700mb low apparently followed a regular track to the west northwest at about 14 knots. However, each time a surface low developed, it immediately tried to move north northwest and weakened rapidly as it moved out from under the low aloft. This is shown clearly by the lower levels of the Guam rawins during the time the center was passing (figure 3-3). The surface center, with very light winds, passed just north of Guam, while the center above 8000 feet passed to the south. Guam actually experienced a dead calm and thick fog during the passage of the center.

After three more days, the 700mb and surface flow became parallel, and Typhoon JEAN developed in the no data area between Guam and Luzon.

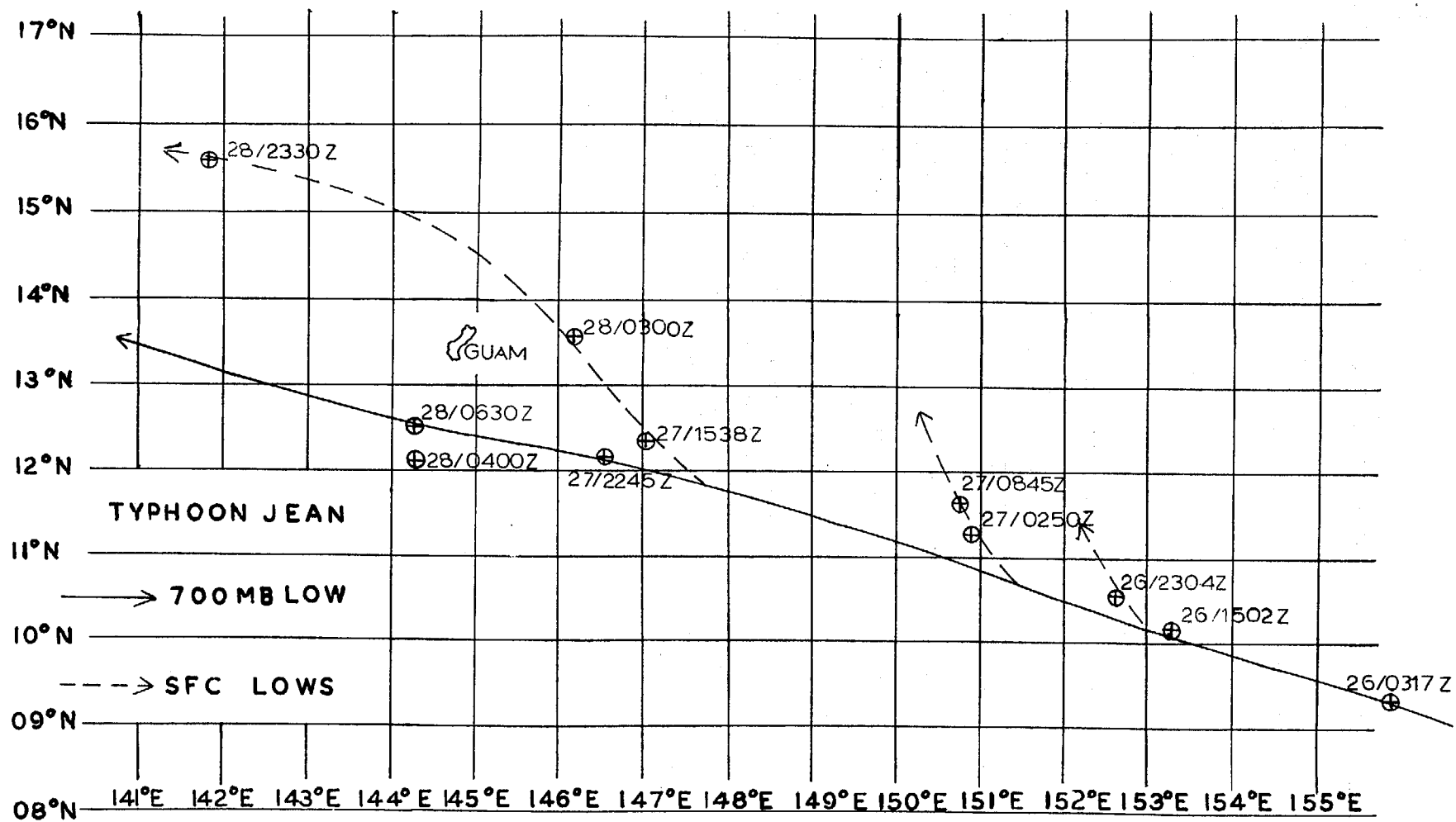


Fig 3-2

E. EXTRATROPICAL SURGE

Following the analysis of extratropical surge in Typhoon HOPE (See JTWC Studies in the 1964 Annual Typhoon Report), a search was made for other well documented examples of this phenomenon. In most cases, it was found that operational reconnaissance did not give the coverage necessary to fully outline the surge process. However, two additional examples have been found which fit the pattern observed in Typhoon HOPE and in 14 other cases observed since 1962 data available indicates the process did occur, although complete documentation is lacking.

Typhoons JUDY (October 1963) and BESS (October 1965) have been plotted, using the moving coordinate technique outlined in the 1964 report. Due to the subjective nature of surface wind reports, only 700mb doppler winds have been analyzed for these two storms, but otherwise the charts are similar to those made for Typhoon HOPE.

Typhoon JUDY has been included in this study because of the large rise in 700mb center temperature at a relatively high latitude and the excellent peripheral data, especially in the south and west quadrants. The track of the storm was very similar to that followed by Typhoon BESS two years later. On the 2nd of October 1963, sparse available data showed a flat temperature gradient of 9-11 degrees C. at 700mb surrounding a small 17 degree center, with maximum 700mb winds of 55-60 knots except for one 80 knot report 30 miles south southwest of the eye. By the 3rd (figure 3-4) a tongue of cold air had penetrated to the south quadrant of the storm, with a 70 knot 700mb wind maximum ahead of it about 100 miles from the center. Reconnaissance center reports indicated an eye 3 miles in diameter with moderate to severe turbulence and maximum 700mb winds of 110 knots near the wall cloud at 022200Z. By 030405Z the center had enlarged to 8 miles in diameter with maximum 700mb winds near the center of 90 knots.

On the 4th (figure 3-5) reconnaissance reported a poorly defined eye, with no strong winds near the center. The cold air had almost completely cut off the warm air tongue at this time, with an 80 knot wind maximum on the leading edge of the cold air tongue. In spite of the cut-off of the warm air tongue, the 700mb temperature at the center rose to 21 degrees at 032100Z and 24 degrees at 040400Z over a very small area.

Here again, no operational requirement could justify a flight on the 5th of October. The last reported data was a flight by a VW-1 aircraft into the center on the evening of the 4th, which found maximum 700mb winds of 67 knots and a center temperature of 21 degrees C.

Typhoon BESS was a large storm with a circulation over 600 miles across and surface winds near 150 knots which moved almost due north near 144E during early October 1965. By the 3rd of October it had turned to the northeast near 31N and accelerated slightly to 12 knots forward speed with winds at both surface and 700mb weakening slowly. The chart for the daylight

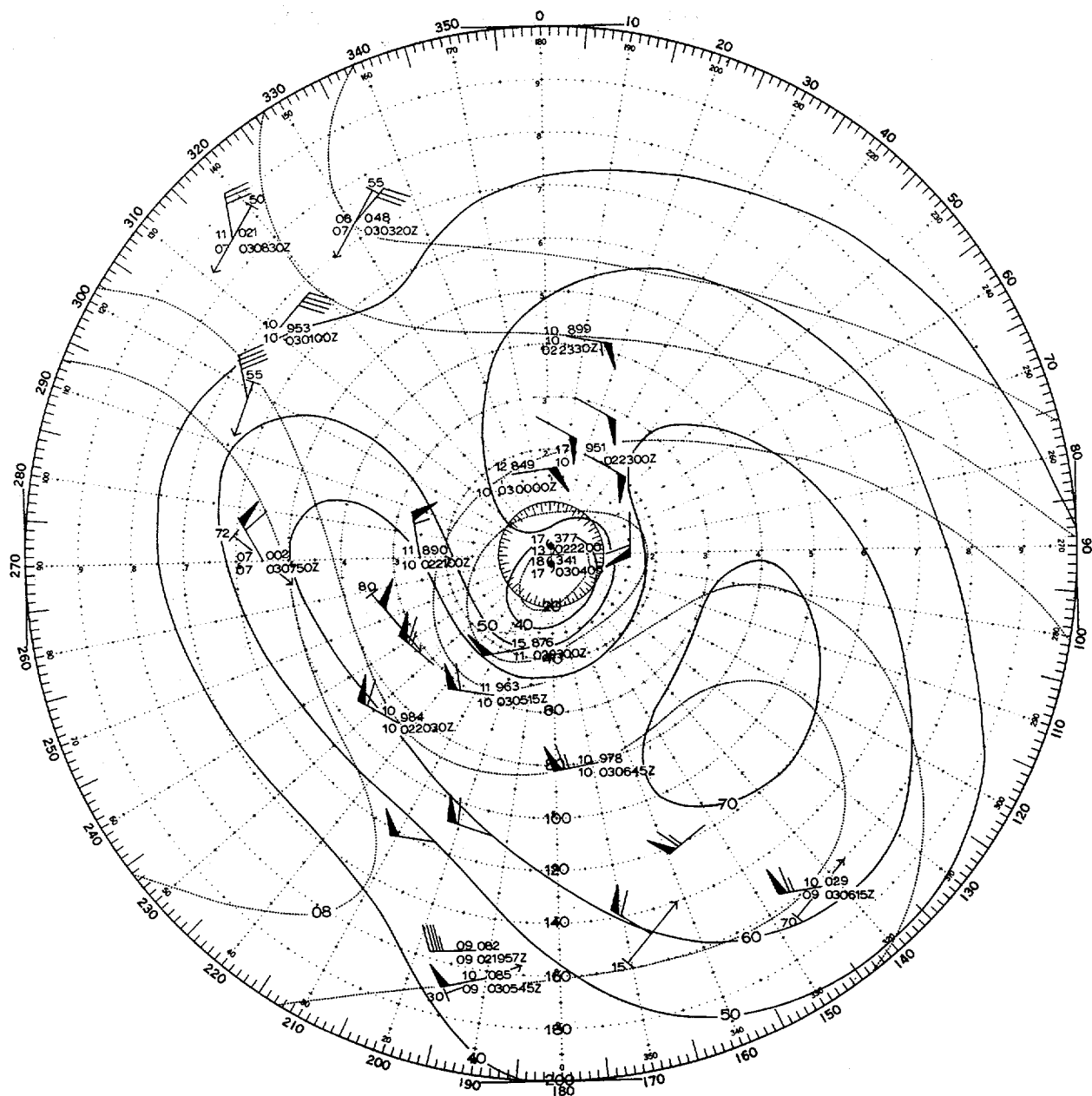


Fig. 3-4

JULY
3 OCT 1963

— 700MB TEMPERATURE
- - - 700MB ISOTACH

fixes October 3rd (figure 3-6) shows a small 60 knot wind maximum in the southeast quadrant about 50 miles from the center and a 50 knot maximum in the northwest quadrant on the leading edge of the cold air tongue. By the next day (figure 3-7) the cold air had swung into the south quadrant and the maximum wind area was lying 60-80 miles southeast of the center, with 700mb winds in excess of 70 knots. A second maximum of about 70 knots was located 80-100 miles northwest of the center on the leading edge of the warm air tongue.

Here again, as in Typhoon HOPE in 1964, no operational requirement could be used to justify reconnaissance of the extratropical system on the following day. However, what peripheral data existed showed the development of a normal extratropical warm type occlusion with surface winds of 50-60 knots.

Typhoon BESS was unusual in that the 700mb temperature in the center rose to a maximum of 21 degrees C. on the 3rd, then dropped back to 18 degrees on the 4th. This was probably due to the extreme northward movement of the center, which was at 35N on the 4th. In almost every other case studied the high center temperature at 700mb remained until the system was completely extratropical.

Another interesting feature of BESS was the movement of the maximum surface wind belt. The maximum surface winds moved from 30-40 miles from the center on the 4th to 60-100 miles from the center on the 5th. Even on a qualitative basis this represents a tremendous increase in kinetic energy in the system.

It appears from the evidence available that extratropical surge is a common phenomenon, especially in early and late season storms. Although the effects are masked by changes due to landfall, it is probable that the same process is responsible for the sudden increases in intensity occasionally observed in the eastern quadrant of storms approaching Japan (and possibly also those approaching the Gulf Coast of the United States). It is felt that a modest research effort, such as a double penetration at 1500 feet and 700mb by doppler equipped aircraft every 6-12 hours while the process is going on would yield considerable useful data.

With the installation of new equipment programmed for reconnaissance aircraft, additional data will be obtained which should determine the relationship between the 700mb and low level wind fields.

In the meantime, from evidence at hand, the following are suggested as some typical changes in a storm becoming extratropical.

1. Wall cloud dissipates and clouds in center become stratiform.
2. 700mb height in center rises 50-100 meters in 24 hours.

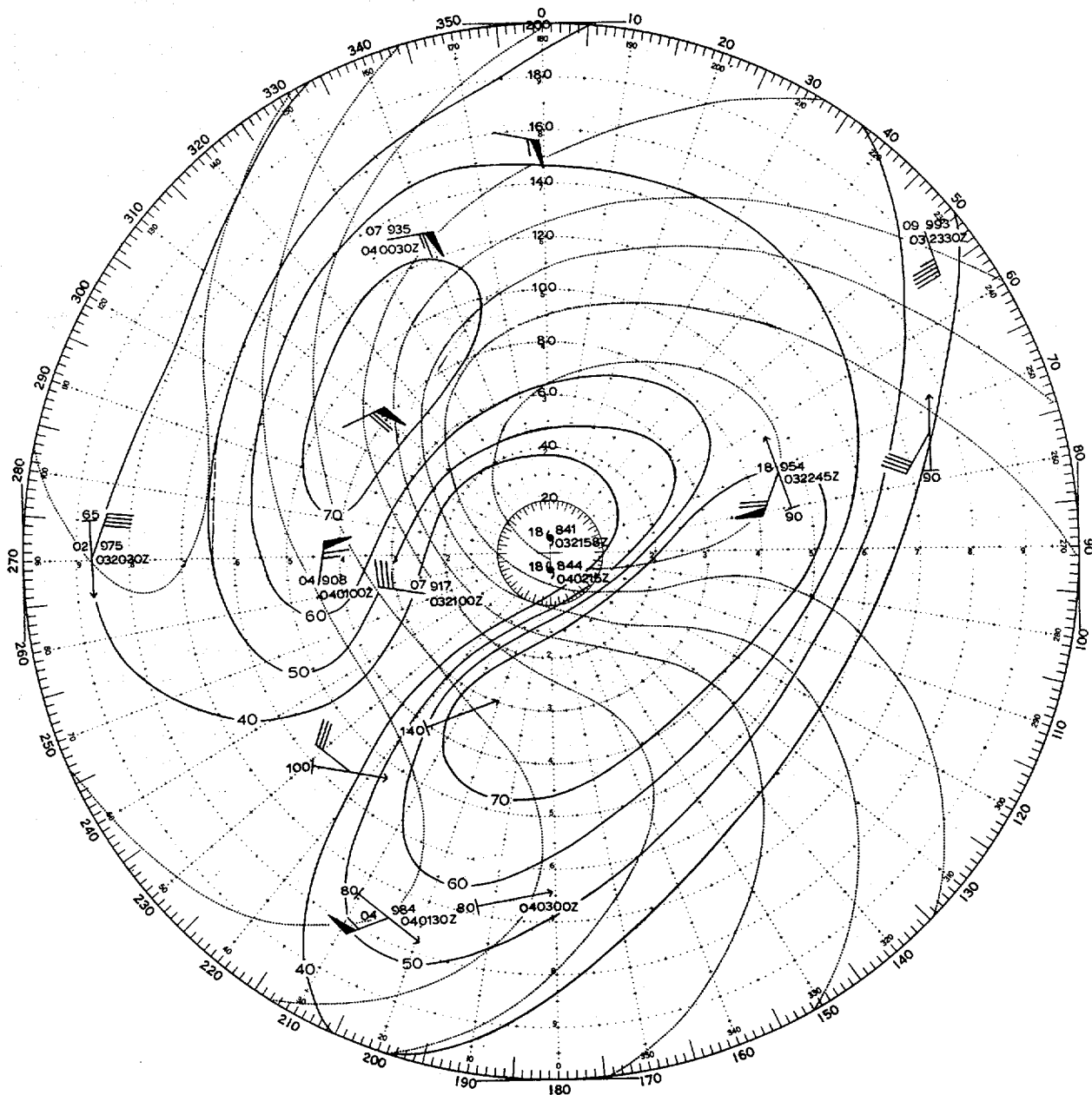


Fig 3-7
 BESS
 4 OCT. 1965
 ——— 700MB TEMPERATURE
 - - - 700MB ISOTACH

F. TIROS VERIFICATION

During the 1965 typhoon season satellite information was used in conjunction with other meteorological data to evaluate the synoptic situation. In some cases the initial information received indicating a suspect area was supplied by the satellite bulletin.

This verification was compiled to determine the accuracy of the data furnished by satellite bulletins. Stage A reports were not verified. Stage B, C, and D reports were verified using average values indicated by figure 3-8 when diameter and band information was not available. Figure 3-9 was used when diameter and band information was available.

Table 3-1 shows the statistics that were used in this verification. The information in columns 3, 8, 9, 10, and 11 was received by message. From a comparison of columns 2 and 3 of table 3-1, the location error in nautical miles (column 4) was obtained. The TIROS wind estimate (column 5) was obtained utilizing the diameter (DIA) and bands (BNDS) (columns 10 and 11 of table 3-1) and entering figure 3-9. The difference between columns 5 and 6 yielded column 7.

When wind speeds changed significantly along the best track the wind speed was interpolated for verification purposes. Otherwise the wind speed at the previous warning time was used. The wind error average over 61 verified cases was seventeen knots. This error would be significant for cyclones in the initial stages of formation but become progressively less significant as the intensity of the storm increased.

The TIROS storm positions were verified against the storm best track. The accuracy of 75 satellite positions varied from 0 to 425 miles with an average error of 81 miles.

NOTE: Figure 3-8 and 3-9 are taken from: Memorandum, U. S. Department of Commerce, Weather Bureau: 18 June 1964, Subject: NWSC Support to Hurricane and Typhoon Forecast Centers

FORMATIVE STAGES OF TROPICAL CYCLONE DEVELOPMENT

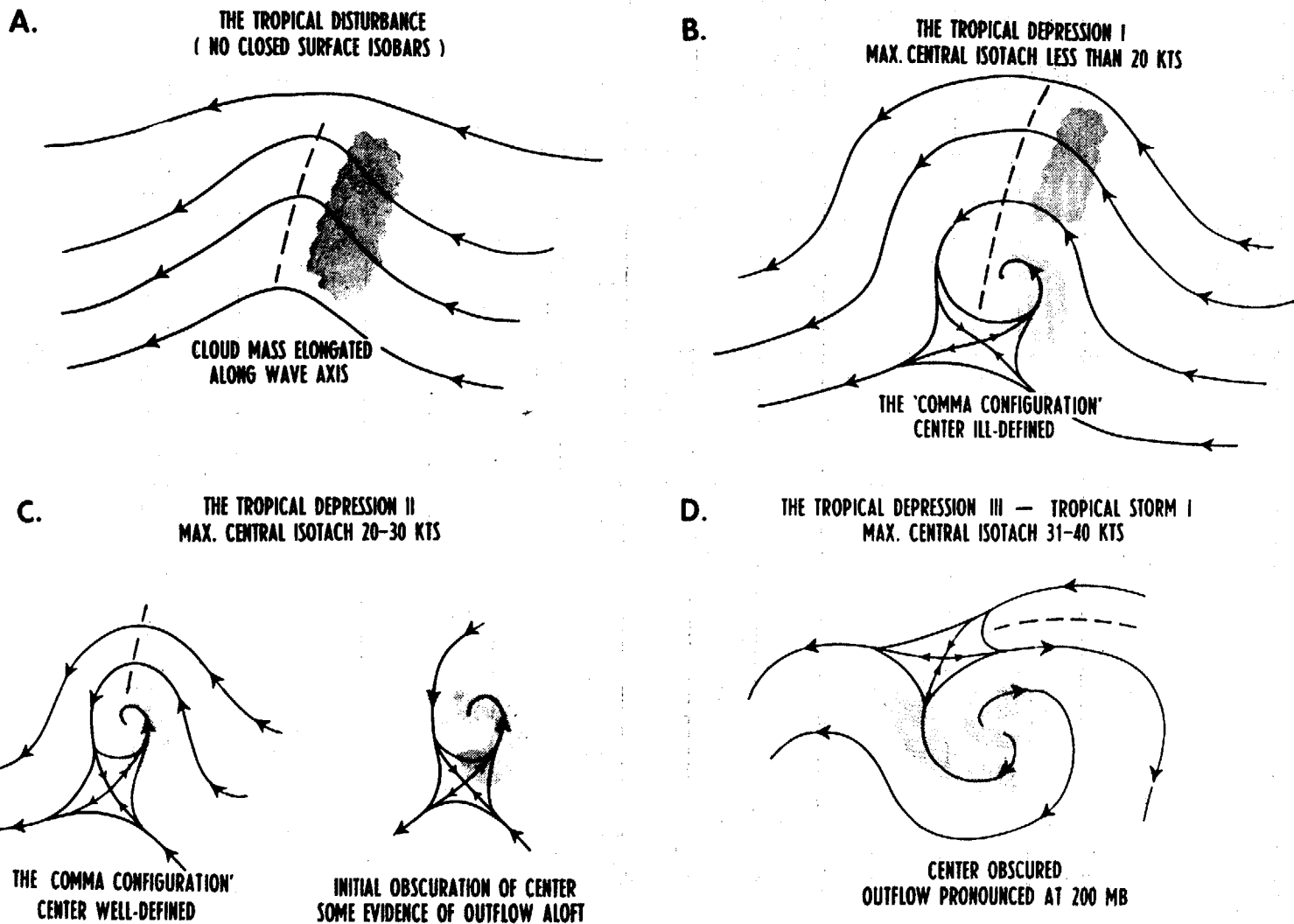


Fig 3-8

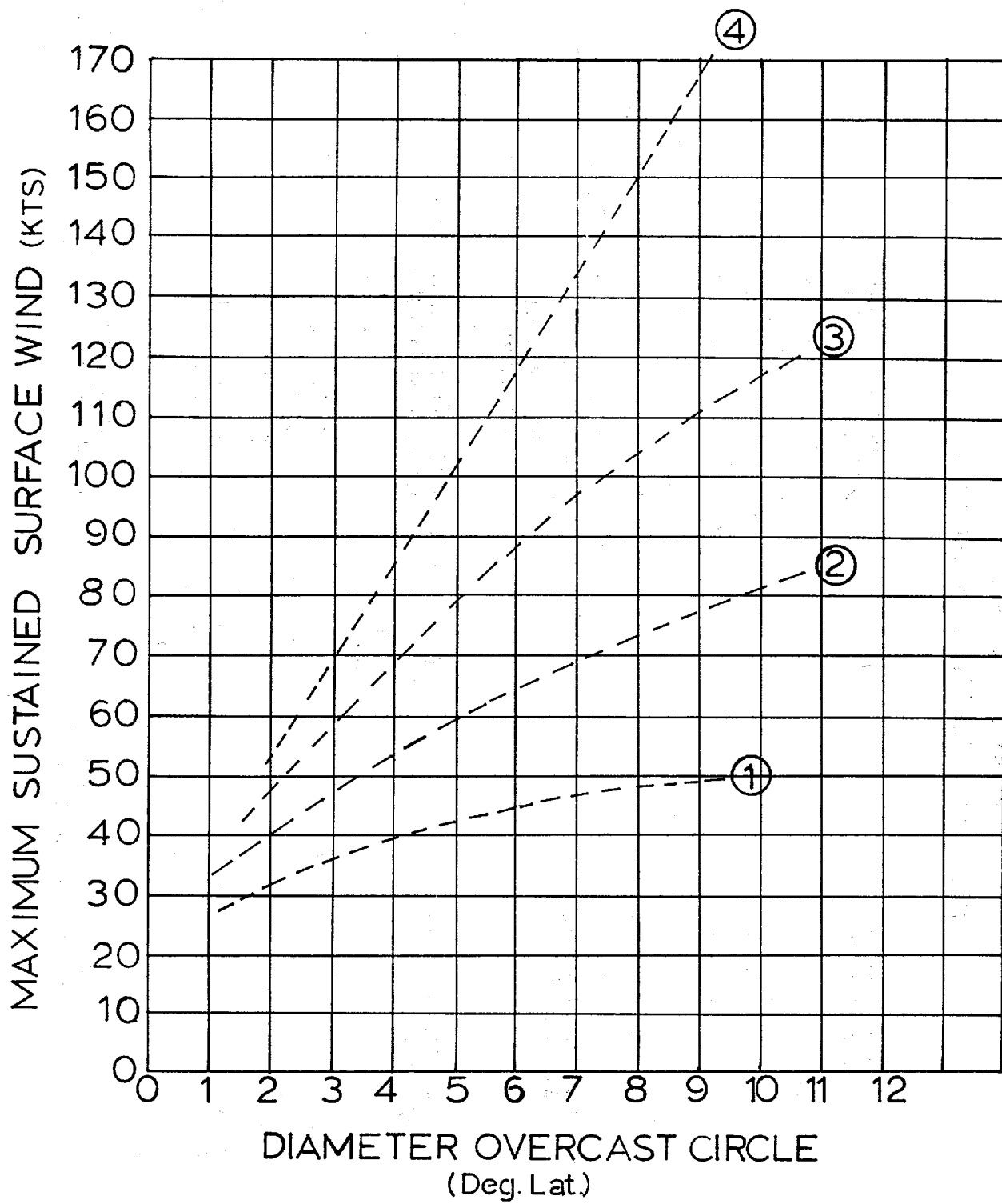


Fig. 3-9

TIROS VERIFICATION STATISTICS - 1965

CYCLONE	POSIT	POSIT	POSIT	TIROS	BEST	WIND	TIME	STAGE	DIA	BNDS
	BEST TRACK	SATELLITE	ERROR	WND	TRACK WND	DIFF	ZULU			
PATSY	13.4N 128.3E	13.5N 127.5E	43	40	Formative	--	190408	D	4	1
	17.0N 129.1E	18.0N 128.0E	86 *65	60	65	-05	210314	X	5	2
SARAH	07.0N 111.0E	07.0N 111.0E	0	--	--	--	140530	-	-	-
	06.8N 108.4E	07.0N 107.0E	87	43	45	-02	150523	D	5	1
	07.6N 104.9E	09.5N 104.0E	123 *70	--	40	--	160711	-	-	-
VERA	10.4N 128.2E	12.0N 127.0E	117 *117	35	35	+00	060426	D	5	0
AMY	09.8N 131.1E	11.0N 128.0E	195 *195	40	25	+15	210216	D	4	1
BABE	15.4N 112.5E	15.0N 113.0E	37	--	60	--	010411	-	-	-
	15.9N 113.8E	17.0N 115.0E	98 *68	56	50	+06	020323	D	4.5	2
CARLA	24.1N 125.6E	23.0N 127.5E	120	70	100	-30	020225	X	4	3
	29.2N 129.6E	29.0N 129.5E	10 *65	20	30	-10	030219	B	X	X
DINAH	11.1N 148.3E	11.0N 149.0E	43	43	25	+18	110056	X	5	1
	11.6N 144.4E	12.5N 142.5E	125	43	--	--	120050	D	5	1
	12.2N 139.8E	13.0N 140.0E	51	60	65	-05	130037	X	5	2
	14.3N 131.6E	14.0N 131.0E	37	90	110	-20	150221	X	5	3+
	14.4N 131.2E	15.0N 131.0E	37	105	110	-05	150511	X	5	4
	15.9N 127.7E	15.8N 128.4E	43	105	130	-25	160212	X	5	4
	17.4N 123.9E	17.5N 124.0E	11	105	150	-55	170158	X	5	4
	20.7N 121.2E	21.0N 122.0E	49	90	140	-60	180152	X	5+	3+
	25.9N 121.5E	25.0N 122.0E	63 *51	37	40	-03	190144	X	3	1

*AVG ERROR PER STORM

TABLE 3-1

CYCLONE	POSIT BEST TRACK	POSIT SATELLITE	POSIT ERROR	TIROS WND	BEST TRACK WND	WIND DIFF	ZULU	STAGE	DIA	BNDS
EMMA	18.3N 124.2E 22.6N 124.4E	17.0N 120.0E 17.0N 120.0E	253 425 *336	-- 48	50 45	-- +03	240251 250250	- X	- 8	- 1
FREDA	13.5N 135.5E 14.4N 127.9E 17.1N 123.3E 18.3N 116.9E 20.5N 110.5E	16.0N 134.0E 13.0N 128.0E 17.5N 125.0E 17.0N 117.0E 19.5N 111.0E	175 83 103 77 65 *101	42 92 105 96 88	70 120 140 85 100	-38 -28 -35 +11 -12	090039 120206 130158 140147 150142	X X X X X	5 7 8 7 6	1 3+ 3+ 3 3
GILDA	13.3N 132.2E 18.9N 118.6E 19.3N 112.4E 21.5N 111.3E 21.4N 108.2E	13.0N 128.0E 17.5N 117.0E 18.0N 112.0E 20.0N 110.0E 19.0N 108.0E	245 123 77 113 140 *140	-- -- 60 54 60	-- 35 60 35 Dissipated	-- -- +00 +19 --	170119 200053 220236 230225 240217	A A X X X	X X 5 4 5	X - 2 2 2
HARRIET	11.1N 143.1E 13.5N 141.3E 17.6N 134.6E	07.5N 140.0E 14.0N 141.0E 17.0N 133.0E	283 35 97 *128	-- 80 80	35 65 70	-- +15 +10	220031 230026 240016	- X X	- 5 5	- 3 3
JEAN	11.8N 150.0E 18.1N 130.6E 23.2N 127.5E 25.6N 126.8E	10.0N 149.0E 18.0N 132.0E 23.0N 127.0E 25.5N 127.0E	123 80 31 15 *62	20 70 78 85	25 75 90 130	-05 -05 -12 -45	270155 010158 030240 040212	B X X X	X 4 4 4	- 3 3+ 4
KIM	30.8N 142.4E	31.5N 142.5E	41 *41	58	45	+13	050143	X	3	3
LUCY	--- 26.8N 143.7E 31.2N 137.8E 33.6N 137.6E	11.0N 177.0E 27.0N 144.0E 31.0N 137.5E 33.5N 137.5E	-- 20 20 10 *17	-- 78 85 102	-- 120 120 120	-- -42 -35 -18	112348 190123 210216 220137	A X X X	X 5 4 5	X 3 4 4

*AVG ERROR PER STORM

TABLE 3-1 (Cont'd)

TIROS VERIFICATION STATISTICS - 1965 (Cont'd)

CYCLONE	POSIT		POSIT		POSIT ERROR	TIROS WND	BEST TRACK		WIND DIFF	ZULU	STAGE	DIA	BND
	BEST TRACK		SATELLITE				WIND						
MARY	19.2N	134.8E	18.5N	135.0E	45	63	Formative Stages	--	150142	X	3.5	3	
	21.1N	129.1E	20.0N	129.5E	66	85		135	-50	170223	X	4	4
	24.8N	120.9E	26.5N	122.0E	121	96	80	+16	190354	X	7	3	
					*77								
OLIVE	25.5N	147.8E	26.0N	147.0E	55	101	130	-29	292209	X	5	4	
	33.7N	146.2E	34.0N	146.0E	21	70	80	-10	312213	X	4	3	
					*38								
POLLY	13.5N	118.4E	13.0N	122.0E	210	32	25	+07	301919	D	2	1	
					*210								
ROSE	17.5N	124.9E	17.5N	125.0E	04	--	90	--	012258	-	-	-	
	17.7N	124.3E	16.0N	124.0E	100	43	95	-52	020244	D	5	1	
					*52								
SHIRLEY	16.2N	142.5E	17.5N	145.0E	165	--	20	--	040146	-	-	-	
	19.0N	142.1E	21.0N	114.0E	162	54	20	+34	050115	X	4	2	
	22.3N	137.1E	23.5N	137.0E	71	70	100	-30	070156	X	4	3	
					*136								
TRIX	18.7N	136.6E	18.0N	136.0E	53	96	85	+11	120035	X	7	3	
	20.7N	133.7E	20.5N	134.5E	37	80	100	-20	130058	X	5	3	
	24.6N	129.6E	24.5N	129.0E	32	--	110	--	160035	X	-	4	
	24.9N	129.9E	25.2N	129.8E	19	118	110	+08	160228	X	6	4	
	30.8N	133.9E	32.0N	134.5E	81	77	100	-23	170200	X	4.5	3	
					*44								
WENDY	13.3N	147.1E	14.5N	149.0E	130	25	25	0	180126	C	X	X	
	21.7N	136.1E	21.0N	136.0E	44	25	35	-10	210138	C	X	X	
	24.2N	132.6E	24.0N	133.5E	52	36	50	-14	230218	D	3	1	
	27.2N	133.7E	29.0N	134.0E	109	40	45	-05	240150	D	4	1	
	31.9N	138.5E	32.5N	139.0E	42	40	50	-10	250121	D	4	1	
					*75								

*AVG ERROR PER STORM

TABLE 3-1 (Cont'd)

CYCLONE	POSIT	POSIT	POSIT	TIROS	BEST	WIND	ZULU	STAGE	DIA	BNDS
	BEST TRACK	SATELLITE	ERROR	WND	TRACK WND	DIFF				
AGNES	17.5N 112.4E	17.0N 112.0E	36	36	45	-09	260300	D	3	1
	21.1N 112.2E	21.0N 113.0E	48	68	60	+08	270802	X	4	3
			*42							
BESS	15.6N 145.6E	15.5N 144.5E	54	60	70	-10	280128	X	5	2
			*54							
CARMEN	14.5N 148.9E	15.0N 149.0E	34	40	55	-15	010118	D	4	1
	23.3N 145.7E	24.0N 144.5E	80	135	150	-15	080130	X	7	4
			*57							
DELLA	26.6N 146.4E	26.0N 146.0E	42	88	75	+03	180133	X	5	3
			*42							
ELAINE	18.1N 112.6E	17.0N 113.0E	68	36	45	-09	110238	X	3	1
			*68							
FAYE	09.7N 147.2E	10.0N 147.0E	21	36	35	+01	200144	X	3	1
	10.8N 140.8E	10.8N 141.0E	13	53	75	-22	210215	X	2.5	3
	12.3N 135.6E	12.0N 134.0E	38	118	120	-02	220237	X	6	4
	14.3N 129.7E	15.0N 129.5E	30	135	130	+05	230157	X	7	4
			*26							

*AVG ERROR PER STORM

TABLE 3-1 (Cont'd)

G. THE STATISTICAL VERIFICATION PROGRAM

This program has been started to provide using agencies with a better measure of the accuracy of tropical storm forecasts and to help point out major sources of forecast errors. It is being run this year with hand computers, and will be programmed for the new CDC 3100 computer to be installed at Fleet Weather Central Guam later this year.

The program provides a breakdown of mean errors by latitude bands for 24, 48, and 72 hour forecasts, and also two measures of dispersion.

1. The root mean square (R.M.S.) of vector errors.

Assuming a circular normal distribution of errors, 63% of the forecasts made should verify within one R.M.S. of the actual storm position and 98% within two R.M.S. (See AWS Technical Report #164, dated August 1962).

2. The R.M.S. of right angle errors. (Equivalent in this case to the standard deviation)

Assuming a normal distribution, 68% of the forecasts should be within one R.M.S. right or left of the track and 95% within two R.M.S.

When the machine program becomes available, it is planned to include a breakdown of errors by quadrant in relation to the storm track. This will point out any consistent speed errors or consistent errors to right or left of track. Also, it is planned to specify whether the track is to the west or east of north to identify any consistent errors made before or after recurvature.

Since the R.M.S. of vector errors should be approximately 1.4 times the R.M.S. of right angle errors for a circular distribution, these two figures can be used as a check on the shape of the "error envelope", that is, to compare speed and track errors. Preliminary analysis of 1965 statistics (see table 3-2) indicate speed errors about 20% greater than track errors. More detailed analyses of this type are planned.

This program is expected to provide a better basis for command decisions involving tropical storms, and also to point out areas of maximum error so that they can be given top priority in developing forecast aids.

	1. R.M.S. OF VECTOR ERROR	2. .707 x R.M.S. OF VECTOR ERROR	3. STANDARD DEVIATION OF RIGHT ANGLE ERROR	PERCENT VARIATION ($\frac{2-3}{2}$)
<u>24 HOUR</u>				
TOTAL	182	129	103	20%
UNDER 20N	161	114	96	16%
20N-30N	162	115	98	15%
ABOVE 30N	263	186	130	30%
UNDER 35N	170	120	100	17%
ABOVE 35N	295	209	142	32%
<u>48 HOUR</u>				
TOTAL	358	253	211	17%
UNDER 20N	314	222	189	15%
20N-30N	333	235	214	09%
ABOVE 30N	469	332	239	28%
UNDER 35N	340	240	212	12%
ABOVE 35N	499	253	204	19%
<u>72 HOUR</u>				
TOTAL	494	349	294	16%
UNDER 20N	397	281	254	10%
20N-30N	463	327	294	10%
ABOVE 30N	627	443	333	25%
UNDER 35N	451	319	295	08%
ABOVE 35N	760	537	284	47%

42

TABLE 3-2

H. FINAL REPORT ON 700MB NUMERICAL GRID

The 700mb numerical grid forecast (See 1964 Annual Typhoon Report) was tested on a total of six storms, using four different smoothing techniques. It was found that, with the data available, no significant objective rules could be developed. Since the present upper air and reconnaissance coverage makes an objective analysis practically impossible, this project has been dropped for the present. With an increase in coverage, especially in the area south of 20N, this might still become a useful objective forecasting tool.

I. CHANGES IN SEA SURFACE TEMPERATURE (SST) RESULTING FROM THE TRANSIT OF TYPHOONS SHIRLEY AND TRIX

Typhoons SHIRLEY and TRIX originated and intensified to typhoon strength over warm tropical waters ($\sim 86^{\circ}\text{F}$) of the Western Pacific. The tracks of the typhoons (shown by dashed lines) were seldom farther than 150 miles apart during their transit. The combined effect from the winds along these tracks was a quantitative change in sea surface temperature (figure 3-12) between the mean temperature pattern of 1-5 September (figure 3-10) and that of 21-25 September (figure 3-11).

Although the typhoon tracks traversed an area of fairly sparse data during the first three days, a definite drop of sea surface temperature greater than 5°F was observed. This decrease of sea surface temperature is believed to be primarily the result of wind mixing of the surface water with the cooler water from below the relatively shallow isothermal layer of 100 to 200 feet.

The typhoons recurved to be a more northerly track in the area of the warmer Kurishio current. Again relatively shallow mixed layer depths (MLD) were encountered (figure 3-13) and wind mixing is considered the primary factor in producing cooler sea surface temperature of greater than 5°F .

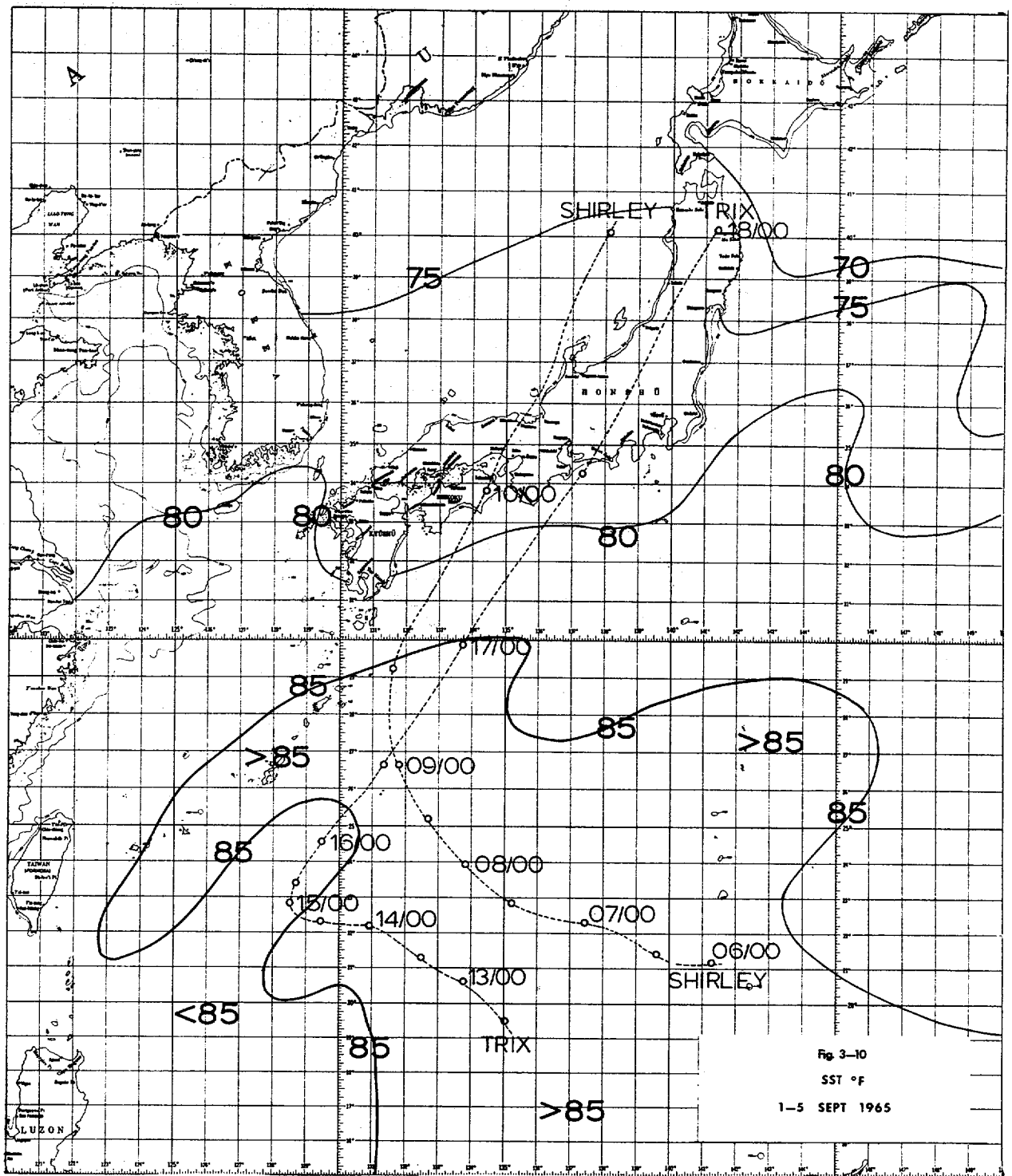
Additional factors which contribute to the decrease of sea surface temperature are:

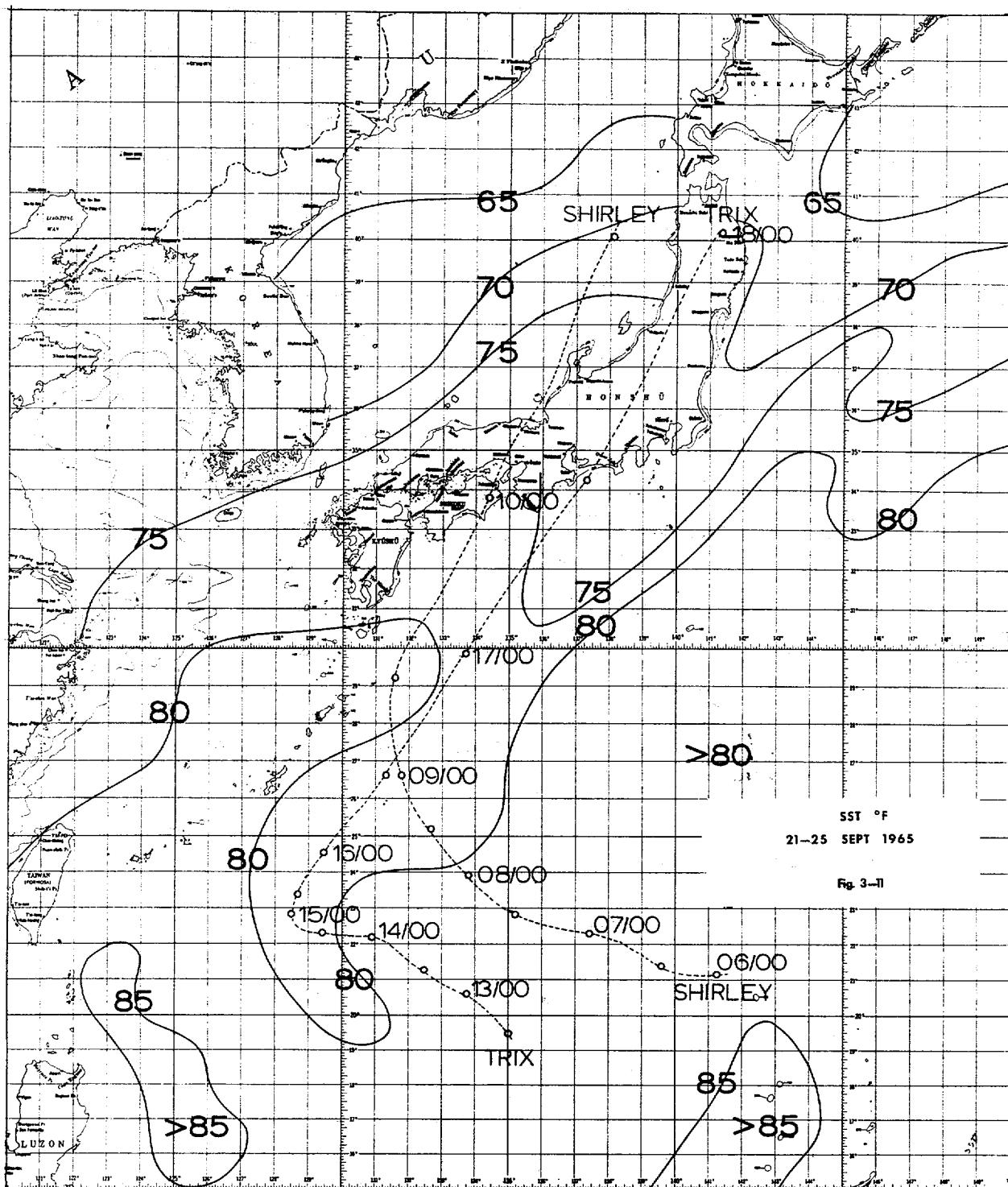
1. The decrease of incoming solar radiation due to increased cloud cover.
2. The presence of cooler water by precipitation.

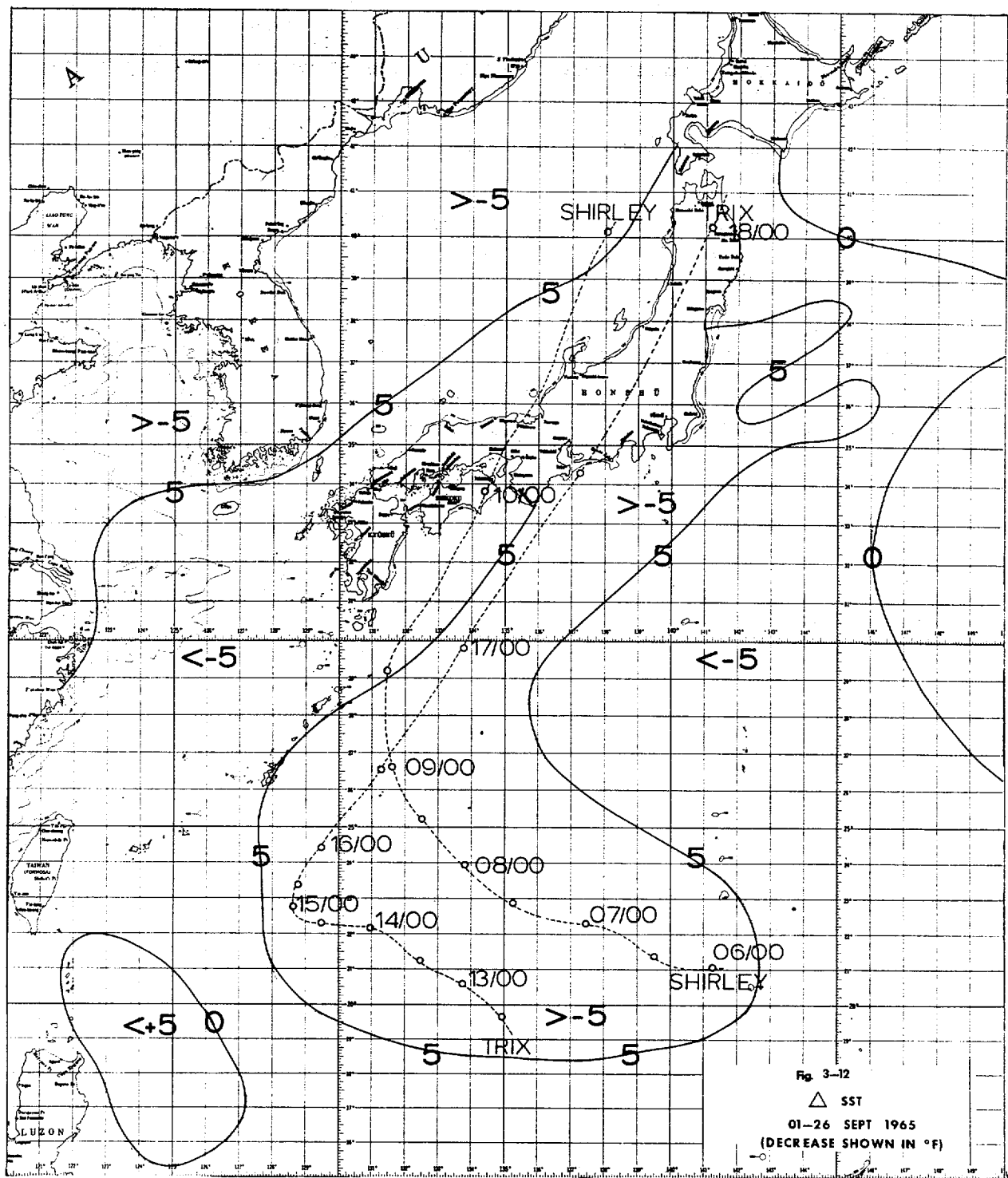
The latter process being more noticeable in lower latitudes where a greater difference exists between sea surface temperature and the precipitation temperature.

It appears evident that the passage of a typhoon over an area will result in a cooling effect on sea surface temperature. The amount of cooling being dependent upon the intensity of the typhoon, typhoon speed, and other factors previously mentioned.

Further research into the effects of typhoons upon the sea surface may result in a prediction method for determining the quantitative cooling in an area under their influence.







3. 700mb temperature in center rises temporarily - may be as much as 6 degrees.

4. Winds at surface near the center decrease rapidly. (Also winds at 700mb, although to a lesser extent).

5. Surge found both at surface and 700mb on nose of cold air tongue 100-200 miles from the center. Secondary surge on nose of warm air tongue 150-250 miles from center.

6. Cold air at 700mb moves around west, south and east quadrants of storm as a tongue approximately 75 miles wide centered about 100 miles from the center. The warm air is cut off as a pocket over the center and gradually driven aloft. (The system becomes extratropical with all the characteristics of a fully developed warm type occlusion.)

J. CHANGES IN MIXED LAYER DEPTH (MLD) RESULTING FROM THE TRANSIT OF
TYPHOONS SHIRLEY AND TRIX

Typhoons SHIRLEY and TRIX attained typhoon intensity in waters having a mixed layer depth of approximately 200 feet and transited over water of continually decreasing mixed layer depth. Within twenty four hours of travel along their tracks, the typhoons appear to have caused an increase in mixed layer depth (figure 3-15), as relatively shallow initial layer depths were encountered. Figure 3-15 illustrates deepening of the mixed layer depth in increments of 50 feet from the original conditions (figure 3-13) and those subsequent to the passage of SHIRLEY and TRIX through the area. (figure 3-14)

Greater horizontal gradients of mixed layer depth are encountered upon reaching the Kurishio Region where 50 to 100 foot mixed layer depth is encountered. The combination of increased wind intensity and the proportionally deeper wind mixing effect over an area of initially relatively shallower layer depths accounts for the greater change depicted in figure 3-15. It may be noted that the mixed layer depth generally increased between 50 and 100 feet throughout the area affected by the typhoons.

During the period of 1 to 26 September there appeared to be a general deepening of the mixed layer depth in the Kurishio Current region (figure 3-15). Although other factors were undoubtedly contributory in this increase, it is believed that wind mixing was the primary influence. It is conceivable that the change in mixed layer depth may be predicted given accurate wind intensities, typhoon movement, existing mixed layer depth and the thermocline gradient in a given area.

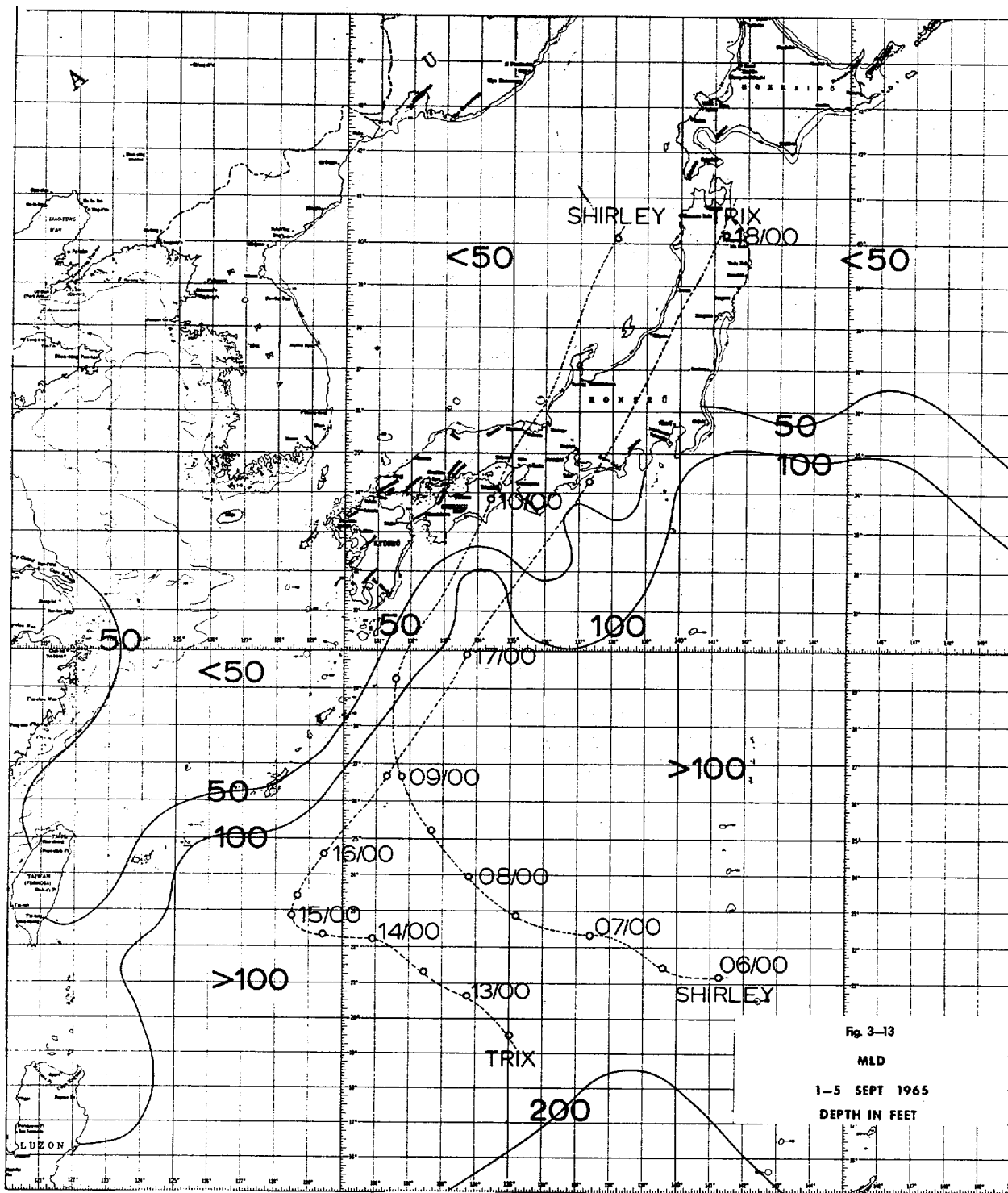
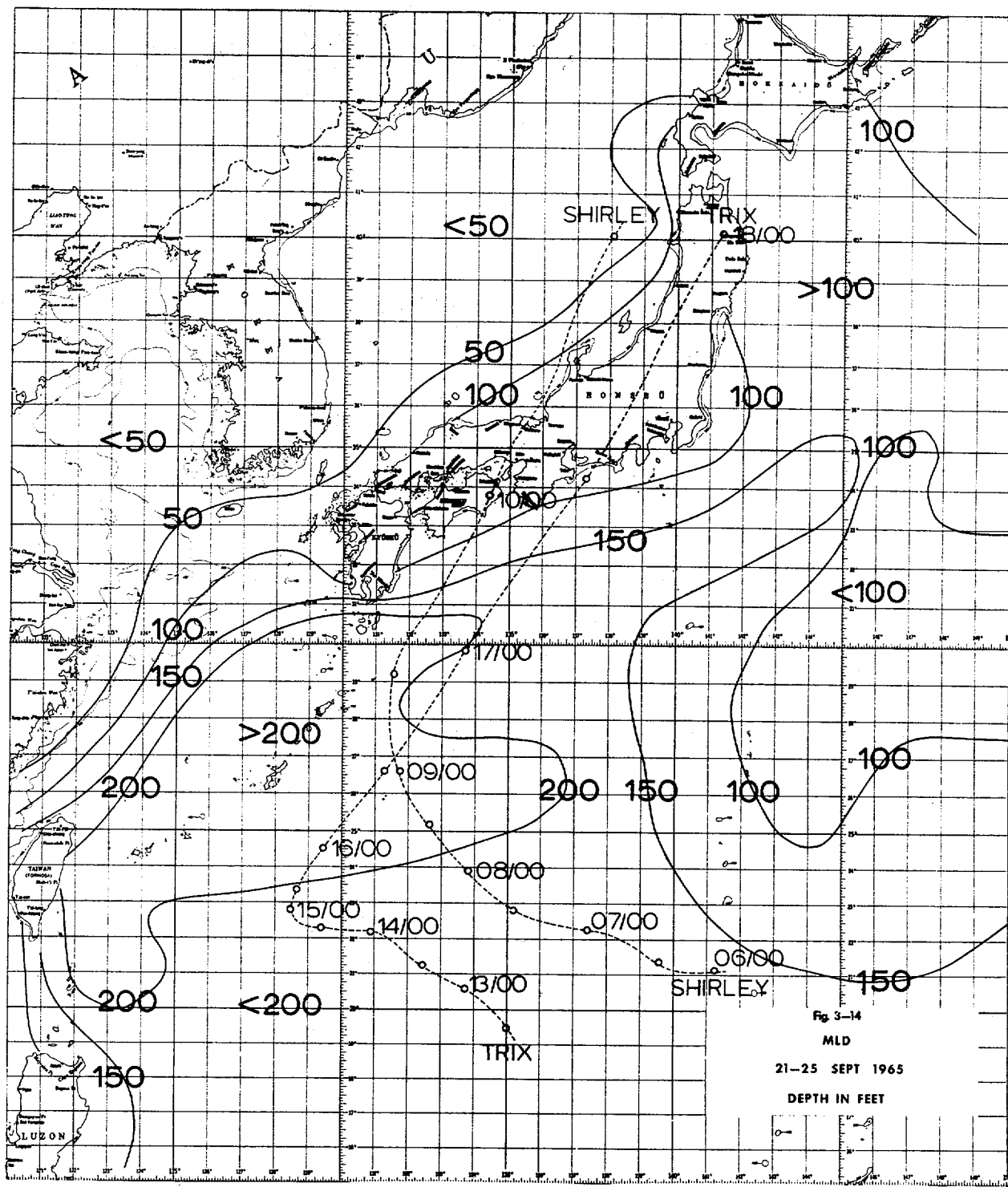


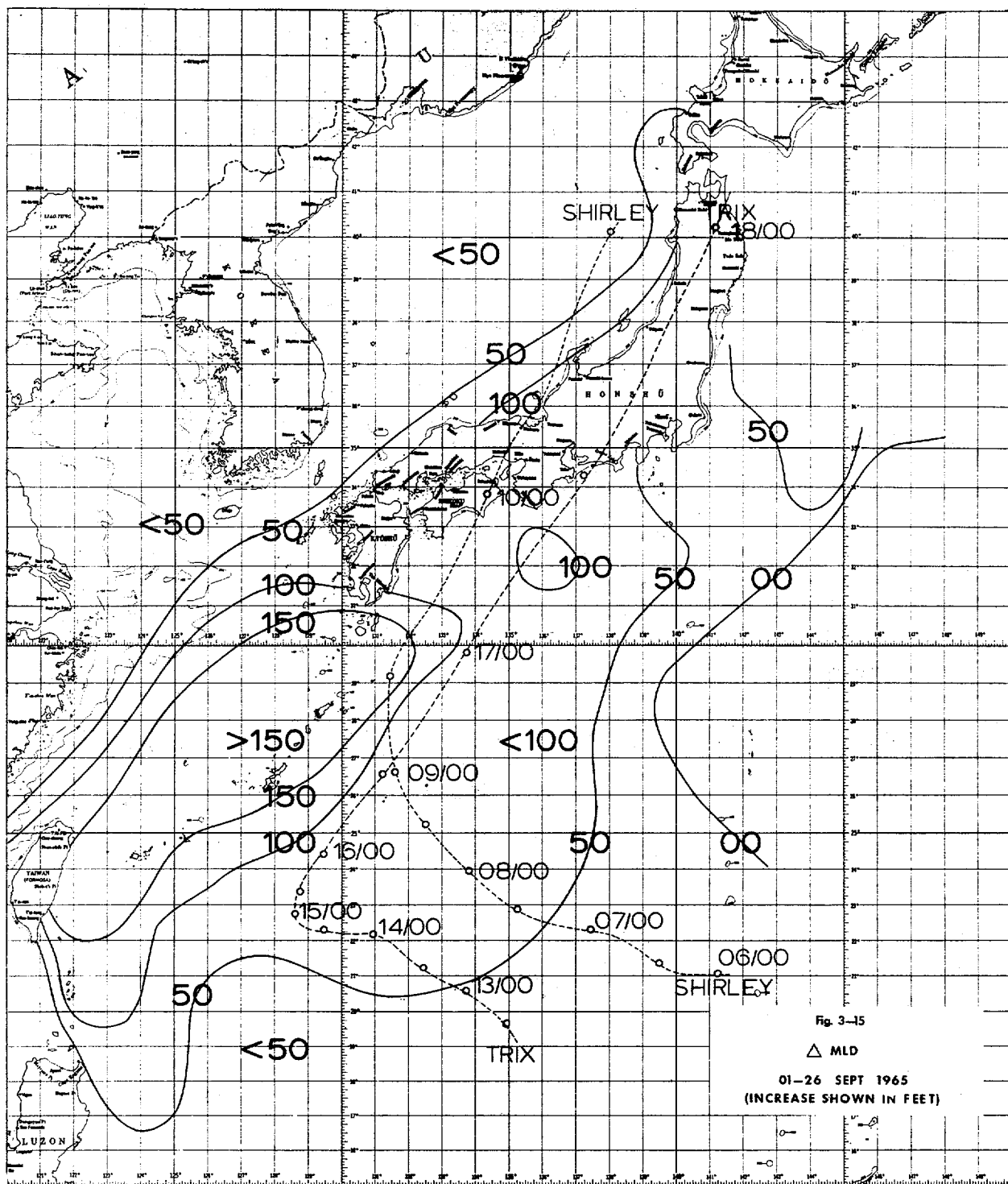
Fig. 3-13

MLD

1-5 SEPT 1965

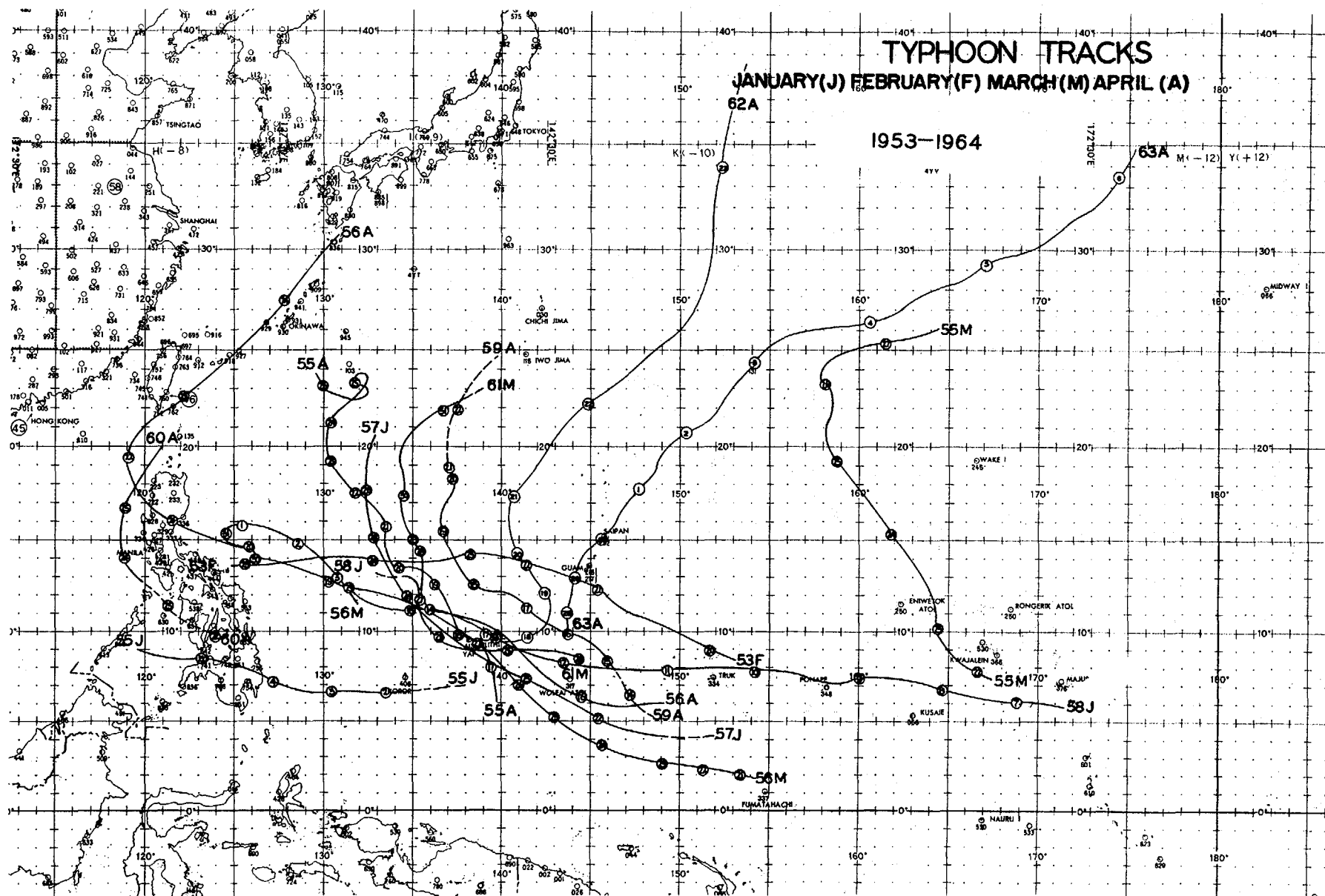
DEPTH IN FEET

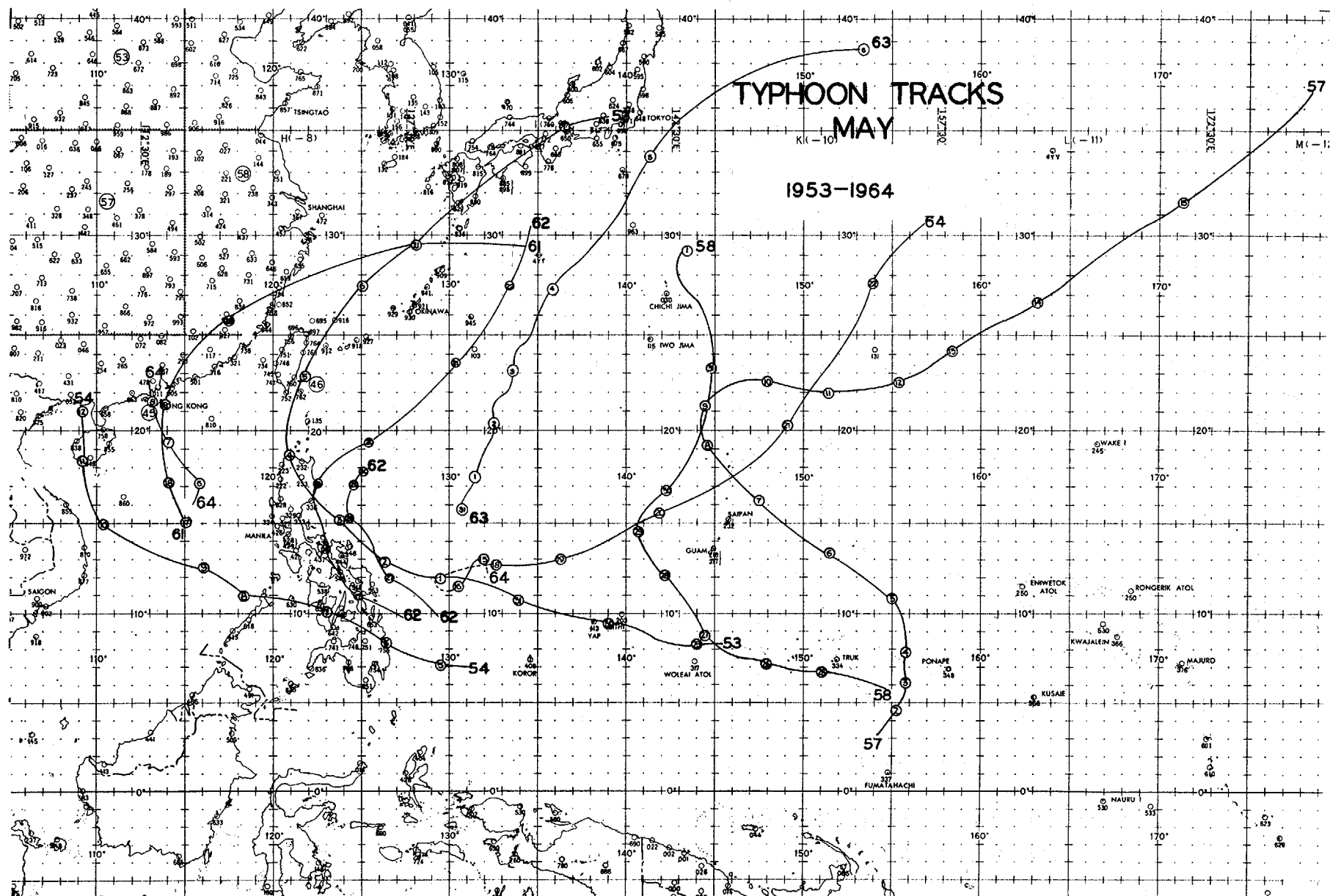




TYPHOON TRACKS

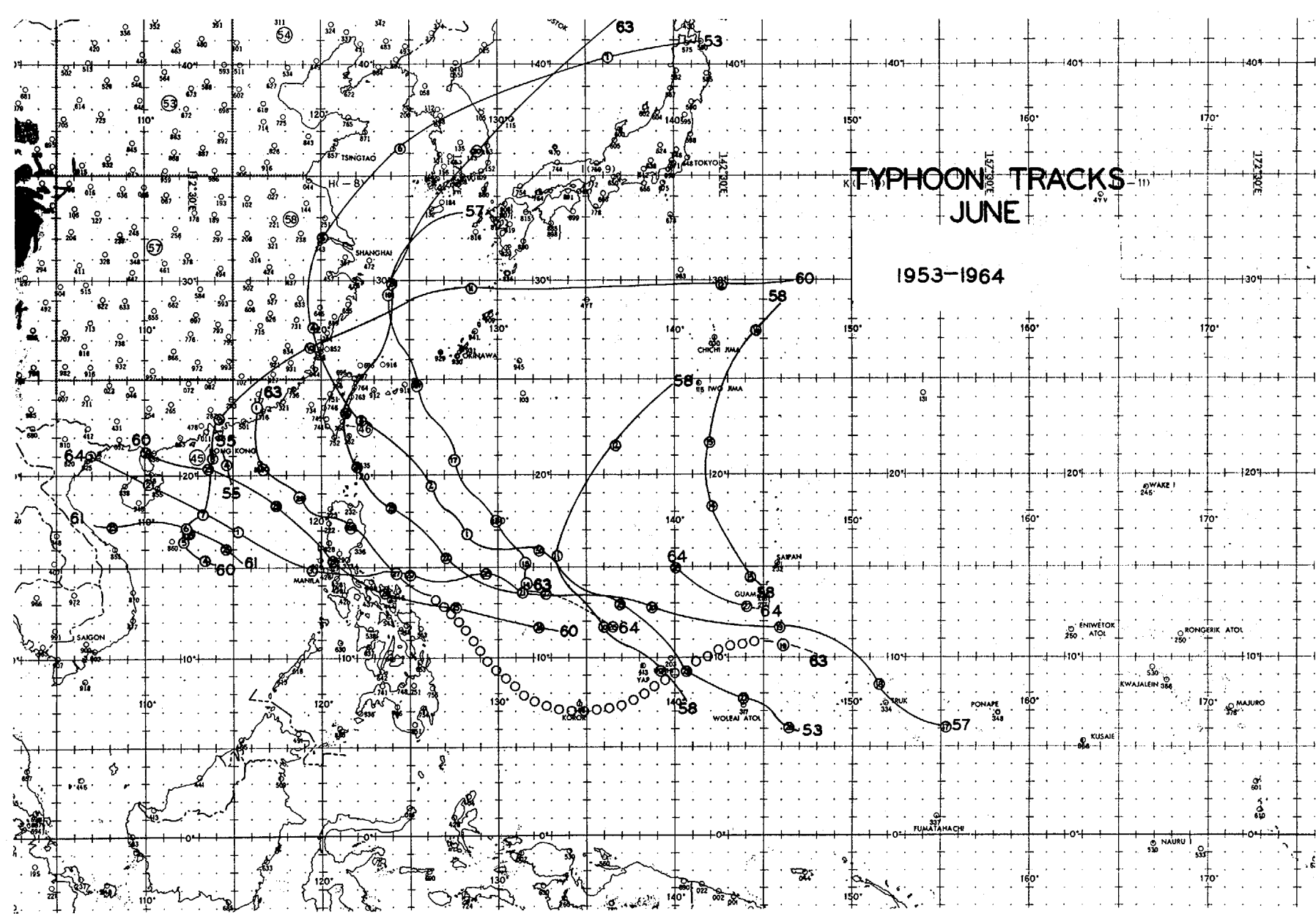
1953 - 1964

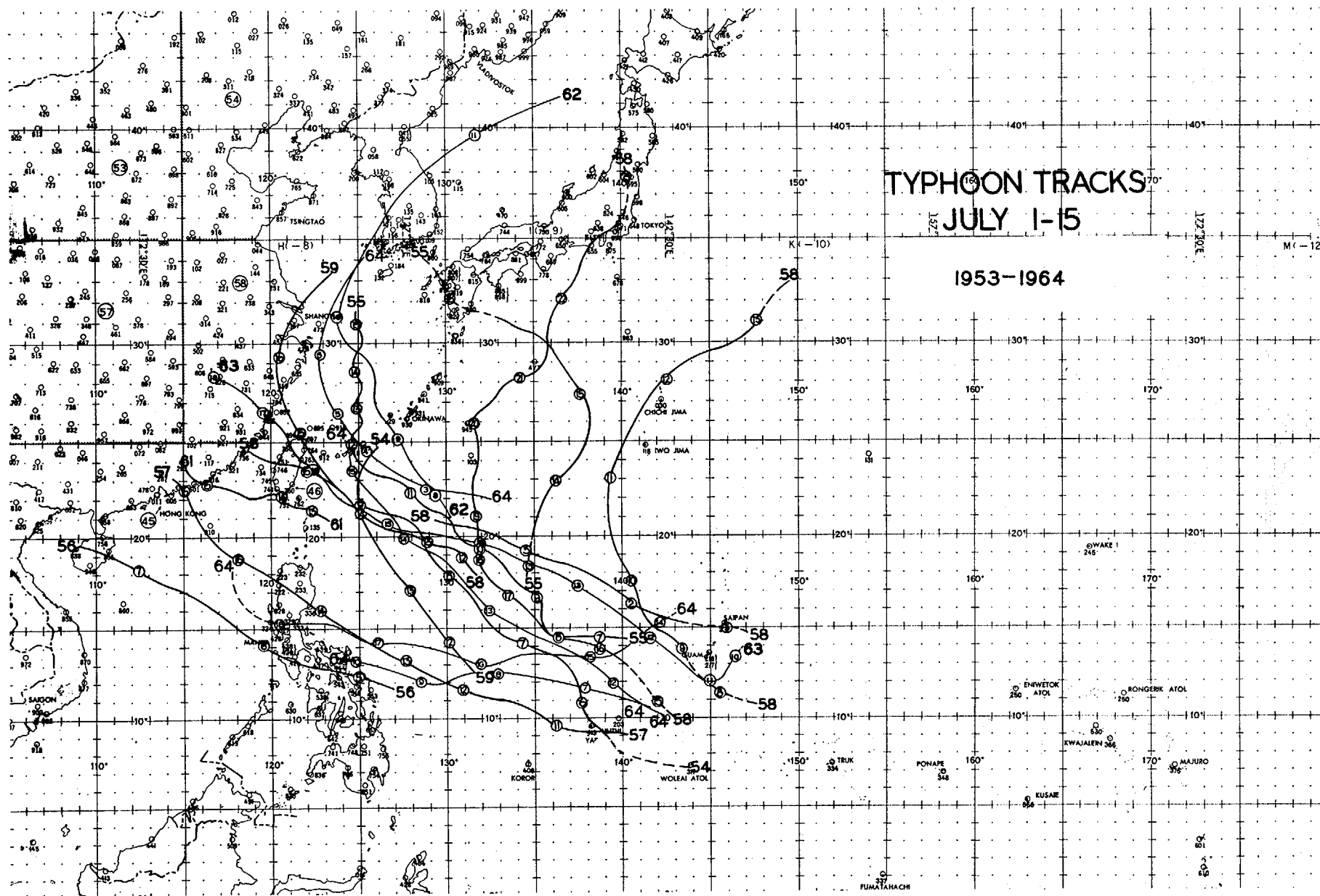


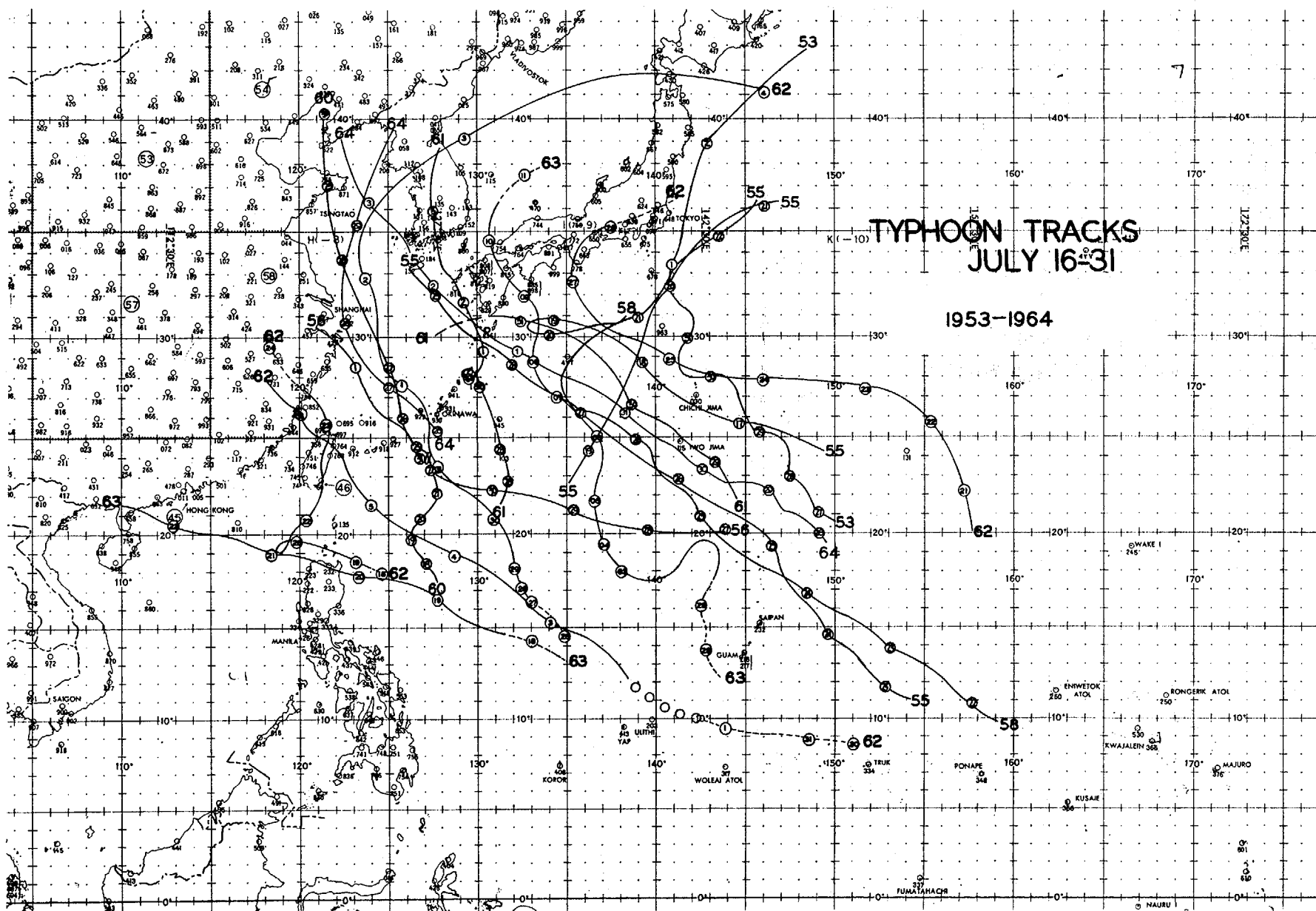


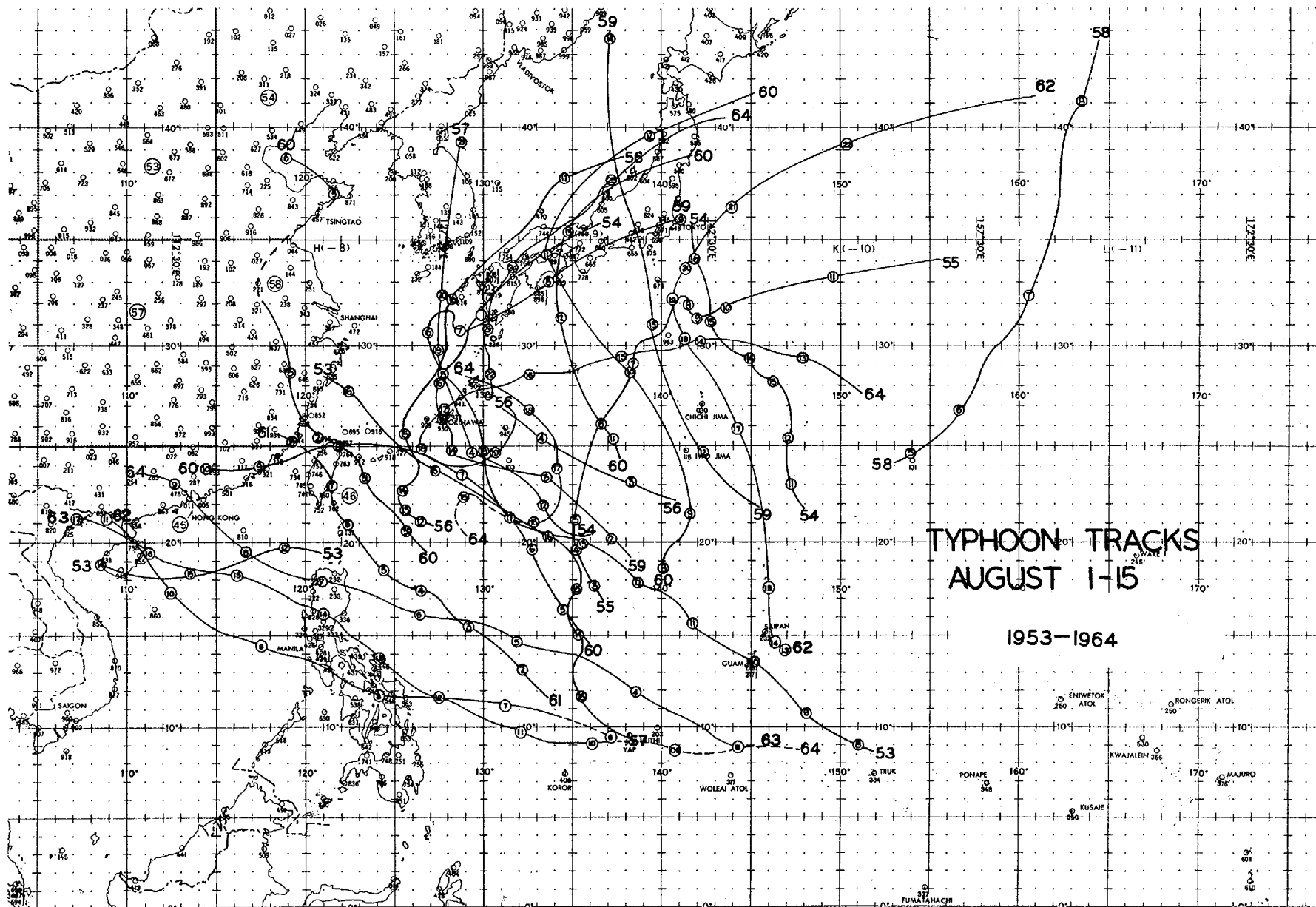
TYPHOON TRACKS JUNE

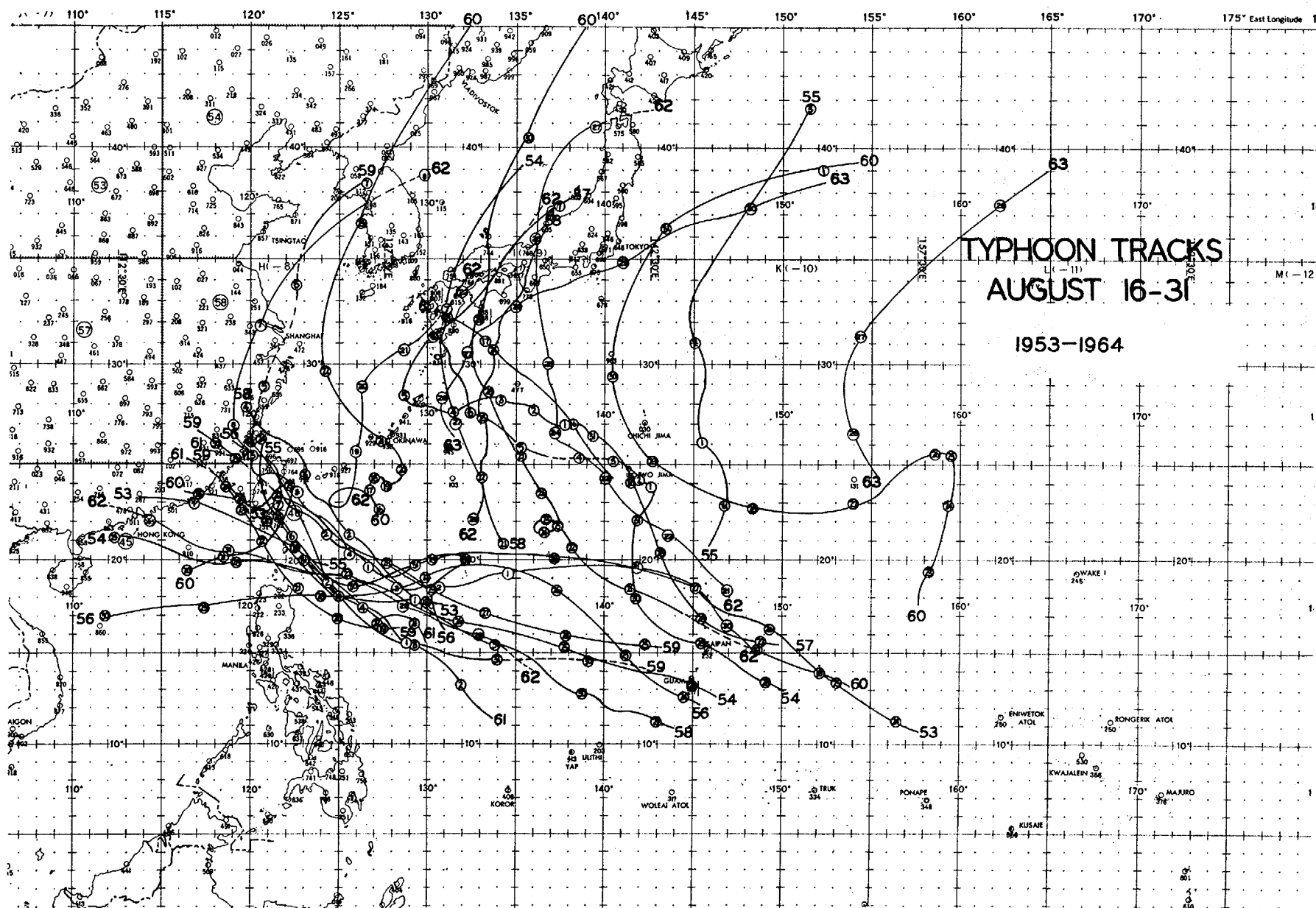
1953-1964

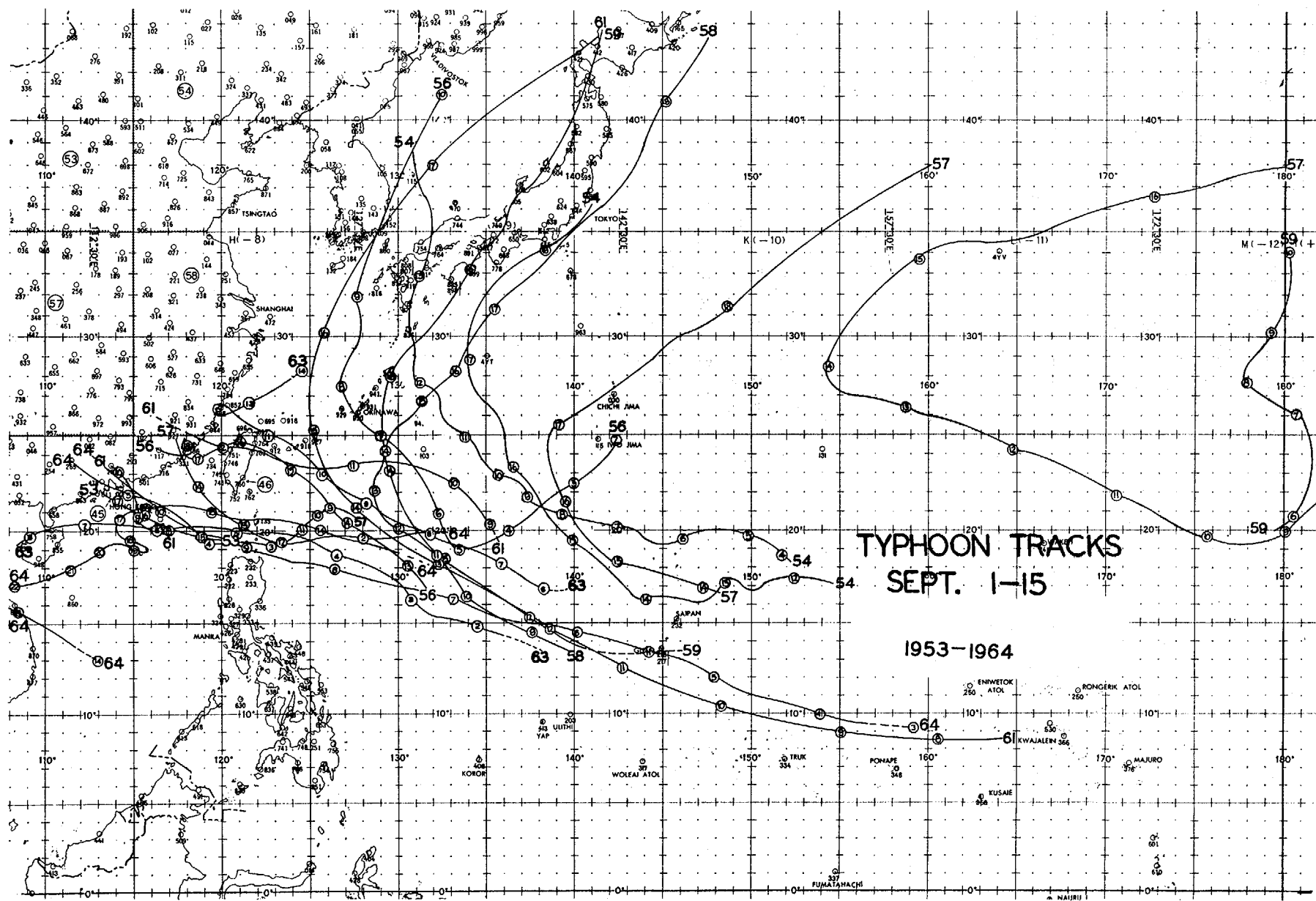


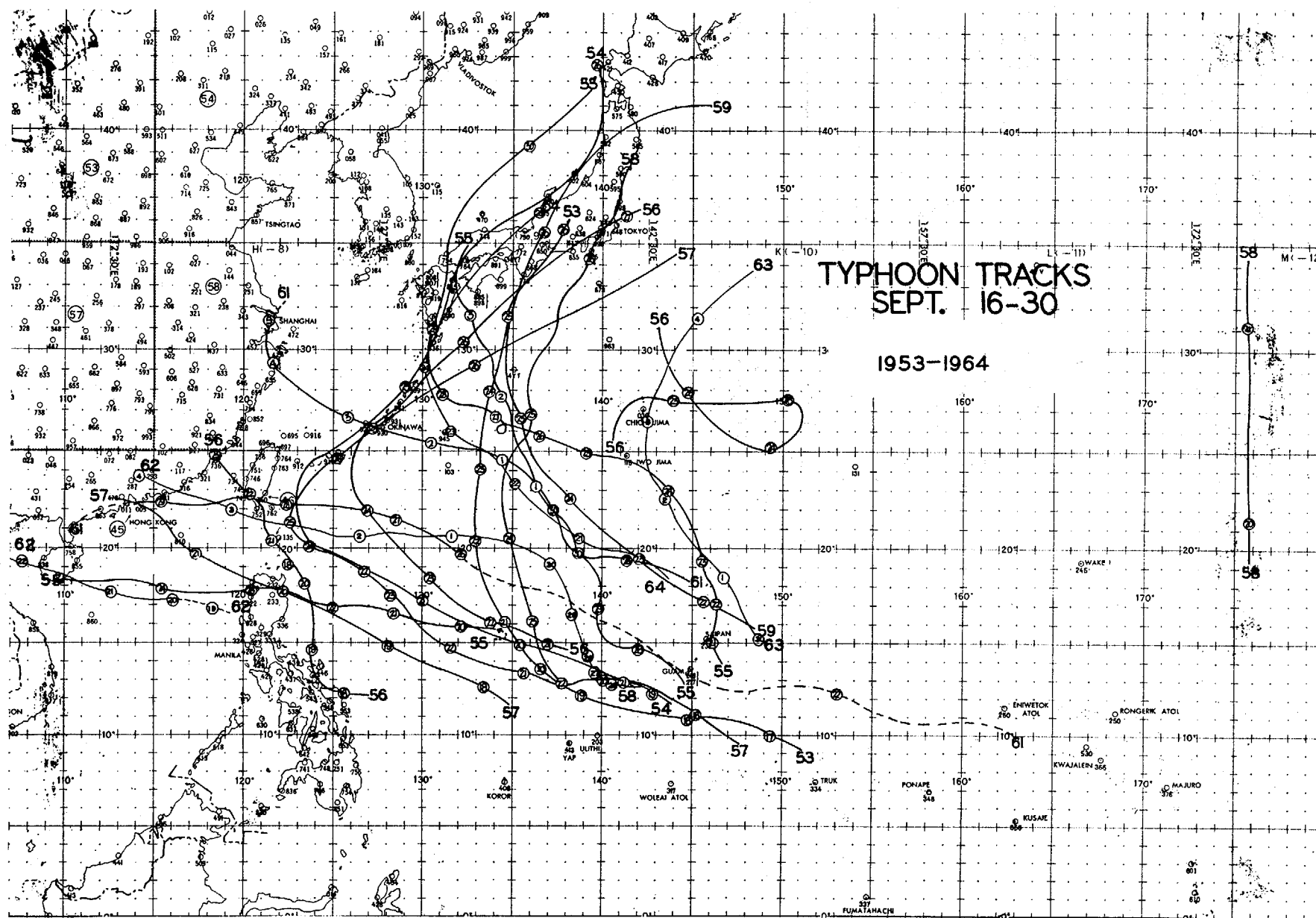


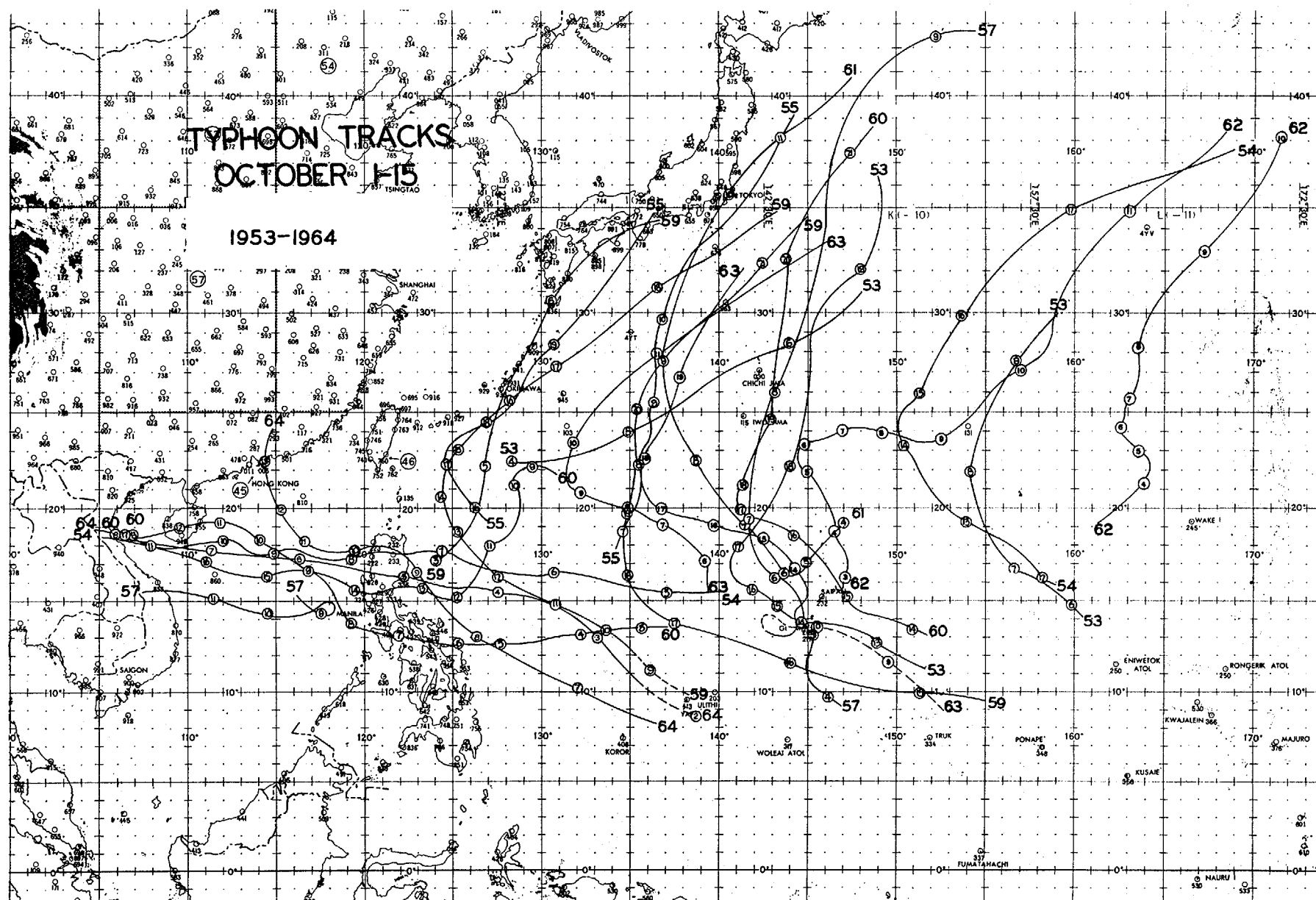


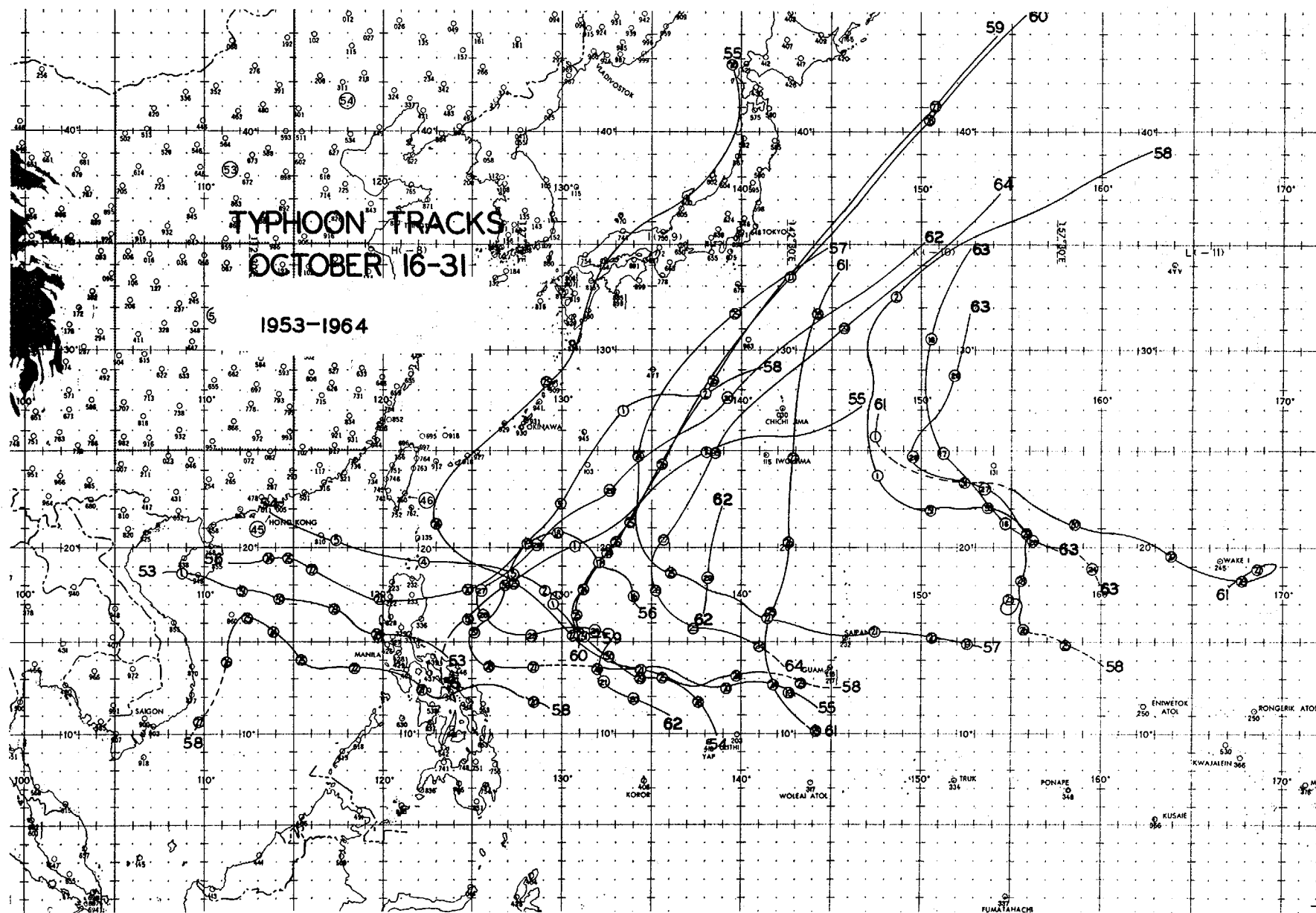


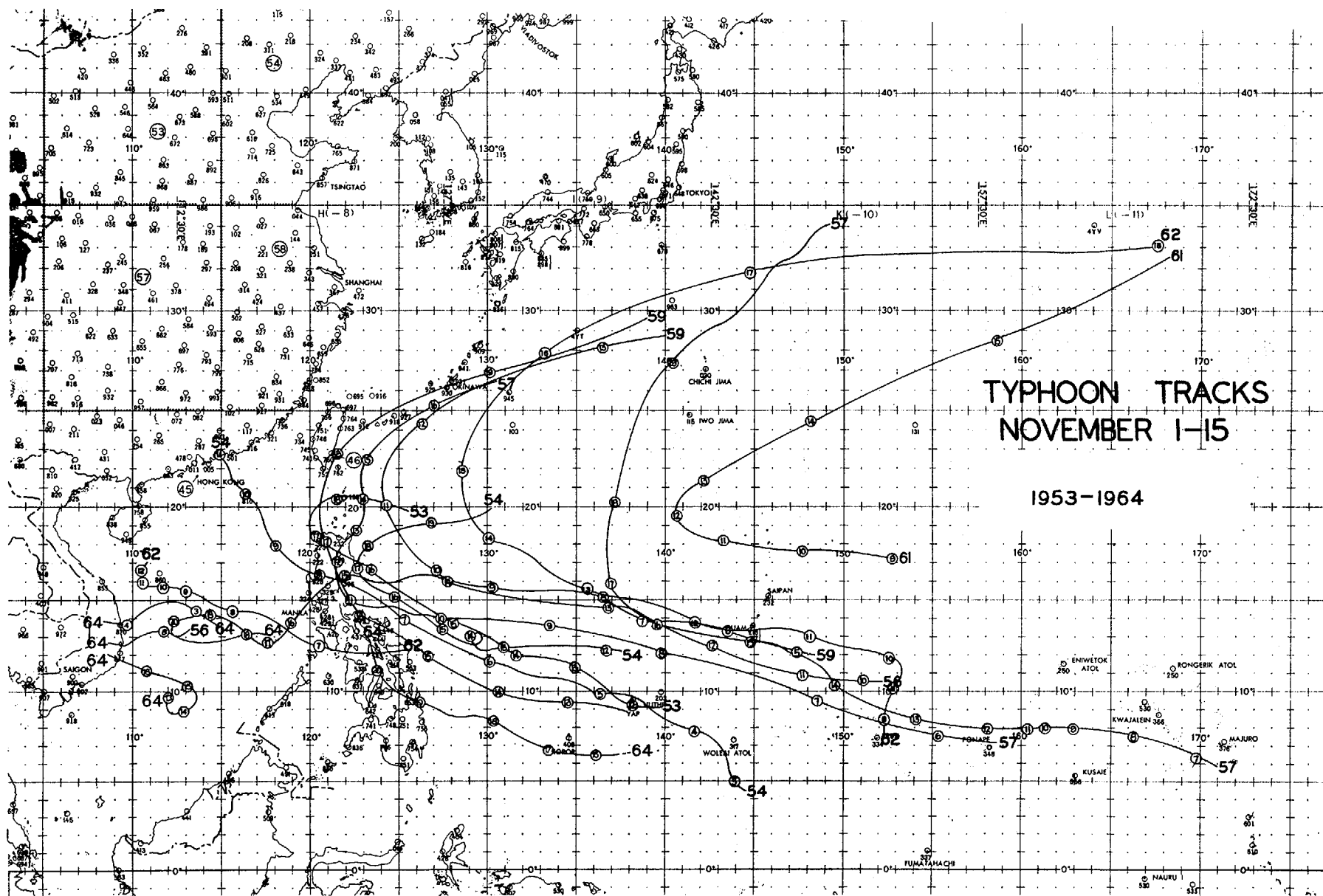


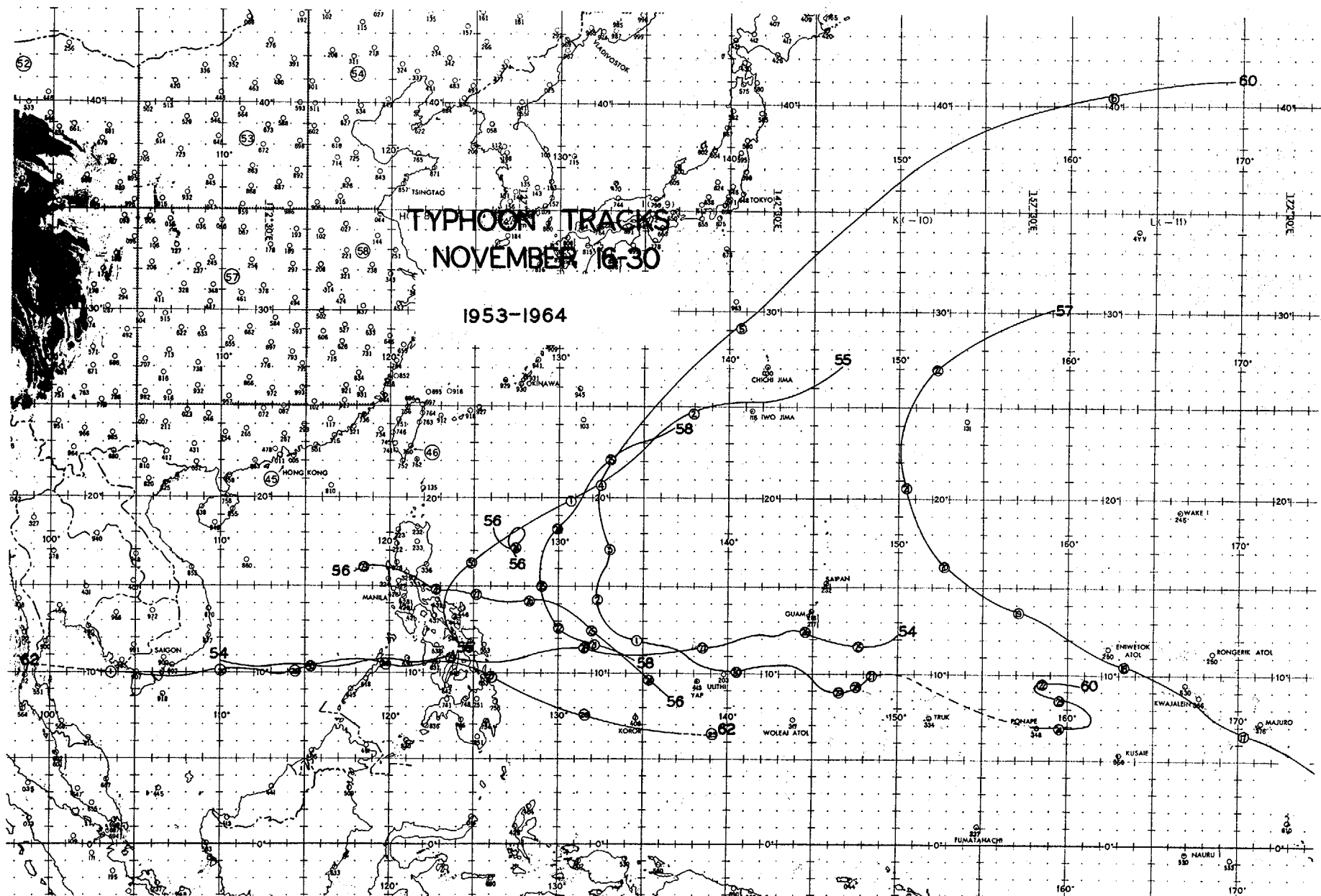




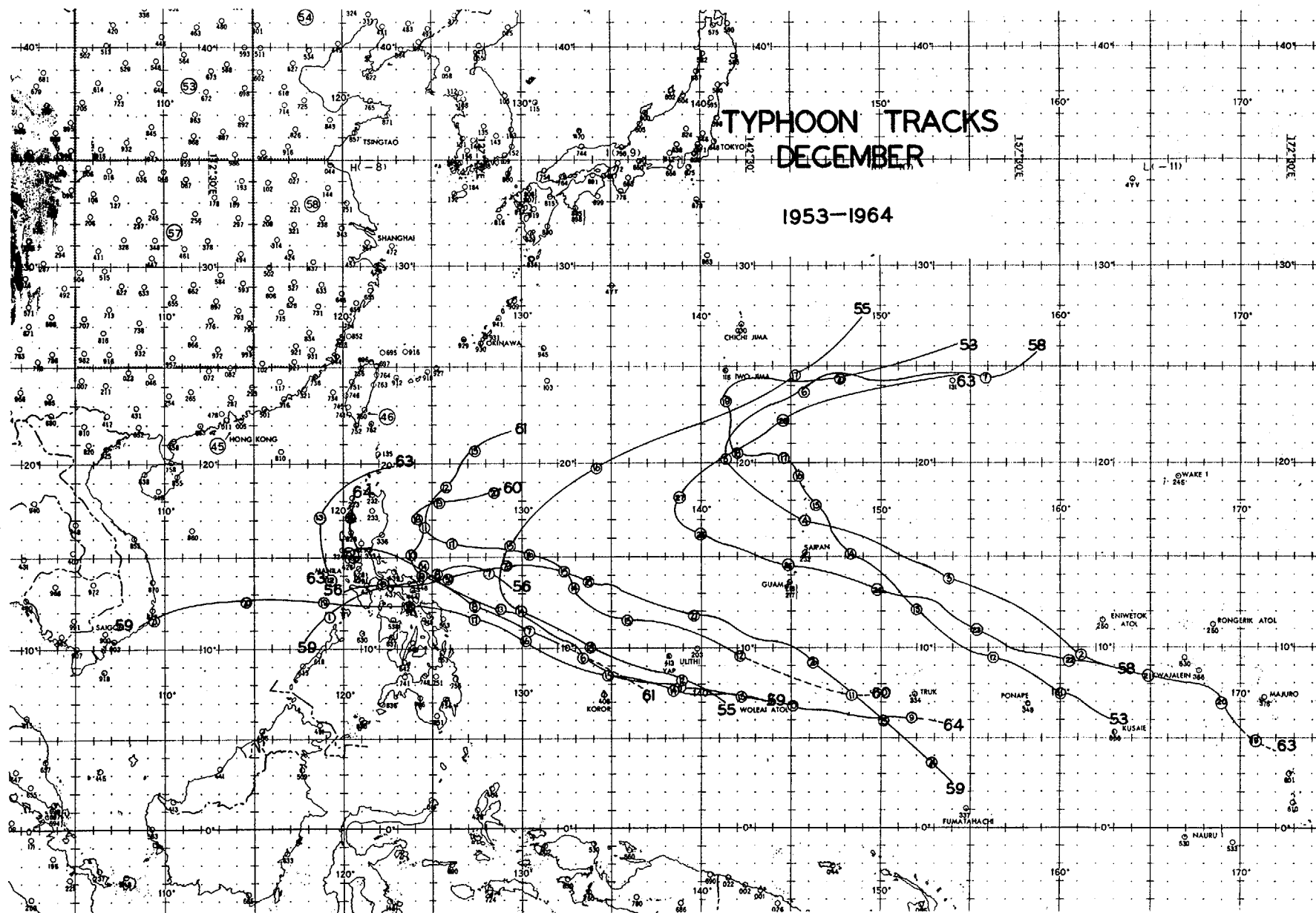








1953-1964



TYPHOON DISTRIBUTION BY MONTH

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
1952						3	1	3	3	5	3	3	21
1953		1			1	1	1	5	2	4	1	1	17
1954					1		1	4	4	2	3		15
1955	1		1	1		1	5	3	3	2	1	1	19
1956			1	1			2	4	5	1	3	1	18
1957	1			1	1	1	1	2	5	3	3		18
1958	1				1	2	5	3	3	3	1	1	20
1959				1			1	5	3	3	2	2	17
1960				1		2	2	8		4	1	1	19
1961			1		2	1	3	3	5	3	1	1	20
1962				1	2		5	7	2	4	3		24
1963				1	1	2	3	3	3	4		2	19
1964					2	2	6	3	5	3	4	1	26
1965	1			1	2	2	4	3	5	2	1		21
AVG.	.29	.07	.21	.57	.93	1.2	2.9	4.0	3.4	3.1	1.9	1.0	19.6